PLANNING OF RURAL ROAD NETWORK
- Case study for Manipur State

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Abstract

Planning a new road network is always an expensive and time consuming process as it requires the addressing of issues like environmental, financial, social and political. The present work aims at developing appropriate models to generate economic and efficient Rural Road Network within the framework of the Pradhan Mantri's Gram Sadak Yojana (PMGSY) Scheme for the state of Manipur. To obtain an economical and feasible road network, a systematic and scientific approach is devised. A detailed database, "administrative block data" is constructed based on the available information of census data, road inventory data and map data to achieve this objective. An attempt is made to remove the inherent drawbacks in the existing administrative boundary of a district block by delineating the area for district blocks using the clustering technique. The two available data sets are used as inputs to the three heuristic models formulated. The first model, Model-1, "Direct Connectivity of District Block and Villages", generates a road network by linking each and every village with the district block. In Model-2, "Road Length Threshold Criteria", distance between nodes is the criterion for establishing various links of the road network while in Model-3, "Threshold Road Length and Population Criteria" distance and other village characteristics such as population is used to establish a link. The three models are tested, first with the pilot district, Tamenglong, and then applied to two other districts: Bishnupur and Churachandpur in Manipur. The model outputs are maximized to get the optimum road network for implementation. The proposed road network is presented visually on a GIS platform, by interfacing the model outputs with ArcView.

CERTIFICATE

It is certified that the present work entitled "***Planning of Rural Road Network - Case Study for Manipur State***" submitted by S. Gopendro Singh, in partial fulfillment of the requirements for the award of Master of Technology in Transportation Systems Engineering, is a bonafide record of research carried out under my supervision and guidance. This work has not been submitted elsewhere for the award of degree.

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1. INTRODUCTION

1.1. Background

The progress of the human race had followed closely by the growth and development of transportation as man had to move from place to place in search of food and shelter. The discovery of the wheel was the most significant milestone in the development of road transport. With the invention of vehicles mounted on wheels, roads were also improved and road transport developed from one stage to another.

Road Transport considerably narrowed down the gap separating producers and consumers and extended the area limits of rail transport to outlying agricultural and industrial centres. Roads are often built in comparatively underdeveloped rural areas, which may not necessarily be inhabited, to stimulate the development and potential economic growth, in addition to generation and distribution of activities along a road network in such regions. Road network development is a basic infrastructural need to bring a change in the economic structure of a country. The extensivity and mobility of road transport are considered to be one of the important factors for modernization and development. Accessibility and mobility are involved in almost everything that developing countries like India seek to achieve. In fact, the entire social and economic life of a nation revolves to a major degree around the use of highways. A general index of advantages to be derived from improvement of highways consists of (i). Development of: a) commerce, b) industry, c) agriculture, d) natural resources, e) intellectual and social life, f) recreational facilities, including touring; (ii). Increase in: a) land values, b) sanitary and medical protection, c) fire and police protection, d) rural mail delivery, and (iii) better defense of the nation (Bruce, 1960).

Both Education and Agriculture plays an important role not only in the development of a region but also, in that matter, that of a society. Education plays the single most important role for the development of mankind. While agricultural production has increased manifold with the introduction of scientific methods and use of new implements, better seeds, fertilizers and pesticides, it is estimated that about 10% of all agricultural produce gets damaged due to lack of proper transport, storage and handling facilities. The development of appropriate post-harvest technology and efficient handling and adequate storage capacity would reduce this avoidable colossal national loss. The role of education and proper communication with the rural masses is crucial for a speedy progress in agriculture and related fields. For a country like India, where the principal occupation of most of the rural population is agriculture, imparting education to the rural mass is imperative for the socio-economic development. Hence, planning, and construction of roads and transportation networks should be done in an extensive and proper way so that dissemination of ideas, knowledge and education, and development of economy of the country can be accelerated. This point has been highlighted in the First Five-Year Plan and subsequent plans of this country. The United Nations' Asian and Pacific Development Institute (UNAPDI) in its programme to eradicate poverty, unemployment and social justice in 1975-76 strongly highlighted i) Higher productivity and increase in production or growth in GNP, ii) Distributive justice or equity in sharing or distribution of benefits of development. The purpose of meeting equity is to achieve basic minimum needs for the underprivileged section of the population in terms of *"Elimination of abject poverty"*. *"Basic Minimum Needs"* include economic and social needs such as food, shelter, clothing, education, health and other public services such as clean drinking water, feeder roads and transportation **(UNAPDI, 1980)**

1.2. Development of Road Network in India

Historically, the indispensability of roads for administrative and strategic purposes had been realized even in the early periods in India. Kautilya, the first Prime Minister of the Emperor Chandragupta Maurya, laid down rules in his *Arthasastra* to regulate the width of roads for various purposes and various kinds of traffic and to provide punishments for obstructing or defiling roads. In the Pathan and Mughal periods also the main road of India received considerable attention. Some of the main highways of the Mughal period received great admiration from foreigners who visited India during that time. Roads were in deplorably bad condition at the beginning of the British rule due to economic and political disintegration that followed the fall of the Mughal Empire and scant attention given to communications by the early British rulers. However, a number of trunk roads, bridges and metalled roads were constructed upon the remains of the old Mughal period. These trunk roads were constructed in the late 19^{th} century prior to the introduction of the railways and maintained under the supervision of British Military Engineers. Public Works Department were formed for the sole purpose of constructing and maintaining roads and other public works when Lord Dalhousie became Governor General in 1855. Works of great magnitudes like the Grand Trunk Road, feeder roads to railway were undertaken by this new department. The Government of India Act 1919 empowered Provincial Governments to develop interstate roads while roads of strategic importance and Grand Trunk Roads were left to the Central Government. The Jayakar Committee that was formed in 1927 had examined and reported on road development in India. The recommendations of this committee was accepted by the Government of India and the Central Road Fund came into existence on the 1^{st} March, 1929 upon the authority of a resolution adopted by the Indian legislature. A Central Road Fund was mobilized in 1931 from the additional duty charged on motor spirit. The constitution of this fund represented the first important measure taken by the Central Government to promote road development in India.

Intensive efforts to develop roads of military importance in the operational areas as well as in other parts of India were made when World War II broke out, as the drawbacks and shortcomings in the road system in India were brought into prominence by World War-II. The necessity for an efficient arterial road system in times of emergency was realized. It was also realized that these roads could be kept up to the mark only if the Center took them over for development and maintenance. These considerations led the government of India to convene a conference of Provincial and State Chief Engineers at Nagpur in December, 1943 to consider the problem of post-war road development in India. The classification of roads into four classes namely, viz.: National Highways, State Highways, District Roads, and Village Roads was the result of the recommendation of this conference. Another important recommendation of the Nagpur Conference was the assumption of financial responsibility for the construction, development, maintenance and control of National Highways by the central government. The mileage targets set in Nagpur Plan were achieved by the end of the Second Five Year Plan, but the road system remained deficient in many respects such as road width, surface standard, weak or missing bridges, etc. The political, economic and social changes that took place after the formulation of the Nagpur Plan necessitated a fresh appraisal of the transport requirements. The Government of India entrusted this task to the Chief Engineers who prepared a new Road Plan for the 20-Year period from 1961 to 1981. The objectives of the plan was to double the intensity of roads from 26 miles (42 kms) to 52 miles (84 kms) per 100 sq miles (259 sq km) of territory. The plan also had provision for 1000 miles (1609 kms) of Expressways with limited access and also grade separation at most crossings **(MTC, 1962).**

Construction of village roads were felt necessary for the socio-economic development of rural India and consideration was given to road development in rural areas during the Third Five Year Plan (Economic Survey, 1995). Specific provisions had been set apart for this purpose in the plans of several states, apart from the provisions available for the development of rural roads under the programme of local

bodies and community development. Under this programme, construction of approach roads linking each village to the nearest road or railhead were to be drawn out by the states on the basis of district and block plans for providing minimum amenities. The Pradhan Mantri Gram Sadak Yojana (PMGSY) was one of the schemes conceived by the Central Government for improving the village connectivity and basic amenities. The PMGSY was announced on August 15, 2000 by the Prime Minister as a centrally sponsored scheme with the objective of connecting within the next three years, every village that has a population of more than 1000 through good all-weather roads and every village with more than 500 persons similarly connected by the year 2007(Sikdar, 2001). The primary focus of the Programme was on the construction of new roads. This Programme covers only Other District Roads (ODR) and Village Roads (VR).

Building of the Road infrastructure requires a substantial proportion of the development budget, so it is extremely important to integrate engineering, social, environmental, political and economical aspects in the planning stage. However, while planning rural roads, one cannot think only of the direct or tangible benefits, that is an investment made in highway construction in rural areas with the sole prospect of future returns or benefits. Savings in transportation costs that will accrue from specific improvements of the highway has to work out to justify the improvements on economic grounds. Some of the intangible benefits which cannot be easily evaluated and justified in cash value while planning a rural road are **(UNECAFE, 1961).**

i) Providing lines of communication to all parts of the producing areas and in shorter times;

ii) Providing direct hauling service to all parts of the producing areas;

iii) Making rural life more attractive and tending to stabilize an optimum distribution of both city and rural population;

iv) Increasing the social and recreational possibilities of both city and rural residence;

v) Increasing the flexibility and strength of the general transportation system of the country in times of war and emergency;

vi) Raising rural land values;

vii) Raising property value in both rural and urban area;

viii) Increasing the range of marketting in respect to the distance permitting favourable selling terms;

ix) Promoting suburban residence of city dwellers and reducing the necessity for congested city living conditions;

x) Providing greater travelling comfort;

xi) Reducing accident on highways;

1.3. GIS in Transportation

A Geographic information System (GIS) has an integrated system designed to collect, manage, and manipulate information in a spatial context. The application of GIS to transportation is relatively new. A number of successful pilot projects and a few broadly introduced applications have effectively demonstrated many potential benefits of GIS for transportation (GIS-T). Applications in transportation planning, management and engineering utilize the available GIS technologies in various ways that involve the collection and analysis of required data and the determination of potential functionality. The capabilities of GIS in the Transportation field will permit the assimilation, integration, and coherent display of data collected and stored by the separate divisions within a highway agency

1.4. Objectives and Scope of the Study

Rural road planning is a complex and time-consuming process. Building of the Road infrastructure requires a substantial proportion of the development budget, so it is extremely important to integrate engineering, social, environmental, political and economical aspects in the planning stage. Most of the studies in transportation

accounts with traffic analysis, safety analysis, urban road development, demand forecasting, route layout techniques using GIS etc. Very few works has been done on the area of rural roads planning. Information available with rural road planning is based in many cases on the population criteria. A scientific and rational approach to rural road planning is very much required for rural India which constitutes about two thirds of the country. To achieve this goal, scientific tools and techniques have to be developed. In India provision for planning and construction of rural roads were given only during the Third Five Year Plan. The Pradhan Mantri Gram Sadak Yojana (PMGSY) launched in the year 2000 is another centrally sponsored scheme by the Central Government for the development of rural roads in modern India. Scientific planning of rural roads is important to get an economical, feasible and lasting road network to serve a community. There is hardly any record for rural road planning in a scientific manner in India.

The present study aims to develop appropriate models for optimum rural road planning by implementing the guidelines laid down in the PMGSY while providing accessibility to the various villages. The objective of the PMGSY is to provide road connectivity, through good all-weather roads to all rural habitations with a population more than i) 250 in hilly/desert areas, and ii) 500 in plain areas, by the year 2007.

The developed model will enable to plan a network of rural roads with maximum social benefits, that is, the proposed network shall maximize population served per km length. The optimum rural road network can be represented graphically using GIS techniques by interfacing the model outputs with a GIS software, ArcInfo/ArcView.

The formulated models for rural road planning are successfully applied to three districts of Manipur, a tiny state in north-eastern India. Both spatial and non-spatial data required in the models are obtained from various agencies of the state.

2. LITERATURE REVIEW

2.1. Introduction

Mechanized transport has been a significant factor in economic and social progress. There is a dynamic force inherent in the improved accessibility of land resources as this offers more varied opportunities to the people. Access to markets and resources are critical to opening possibilities for trade and economic growth. Physical mobility is considered a personal prerogative and influences the quality of life. Road transport has now become, more than ever before, an essential ingredient of a better and fuller life. Good Transportation ensures better health, education and better utilisation, organisation and administration of resources. Besides these, Transport is one single important factor on which hinges the entire industrial activity of a country. Inadequate provision of road transport in rural areas has a direct impact on the agricultural efficiency and production of a country. The Indian Road and Transport Development Association in 1943 made an evaluation of the economic benefits of an adequate system of rural roads. Their conclusion was that roads repaid 277 percent of their cost to the community and created huge increases in the revenues of railways and government. This has been illustrated by "*Friendship Highway*" built in Thailand. The Friendship Highway has transformed partially used jungle land along its hundred-mile route into highly productive and prosperous farms within a short period of only three years, with the result that the production of sugarcane, vegetables, banana and other fruits is trebled, and export of substantial surplus grain to Japan (Kasiraksa, 1963). Road transport has become not only the artery and vein of the modern industrial economy, but also the main assurance of national security.

2.2. Need for Development of Rural Roads

Among the aspects of rural life affected by highways are: i). the methods of farm operations (e.g., the types of crops grown and marketed and ease or difficulty in obtaining labour and supplies), ii). the social, educational, and cultural opportunities available in rural areas; iii). the rural land values (ERD, 1964). Provision for development of rural roads to meet the basic amenities of rural people was first made available in our country under the Twenty Point Programme that was resolved in the Nagpur Plan in 1943. However, planning of rural roads in India was only considered in the Third Five-Year Plan (Economic Survey, 1995). Similar provision is also made under the Pradhan Mantri Gram Sadak Yojana. With the advancement of technology as well as techniques, a rational and scientific approach is desirable to obtain an economic and feasible rural road plan to serve a community.

2.3. Data Required for Rural Road Planning

While rural road networks planning is being done, the master plan need to be prepared at a level which is convenient from the point of map preparation, data collection and obtaining approval of local public bodies, such as Panchayat Samiti, District Council, etc. (Sikdar, 2001). The Master Plan data for rural road network should be collected/prepared at the Block level and then integrated at district level for the master plan. The preparation of a scientific Master Plan for rural roads requires various data, preferably a computerized database consisting of a) Habitation data, b) Road Inventory data, c) Map data and d) Census data are required for rural road planning. The decennial census data has been found to be used as input data for the transportation planning in United States since 1960s due to the rising costs and diminishing local resources which forced most urban area planning agencies to forego their own large scale data collections. (ITE-TCIR, 1986). The 1991 census data is collected for constructing a GIS database.

2.3.0. Habitation Data

In general, a habitation can be defined as a cluster of population living in an area, the location of which does not change over time (Sikdar, 2001). All habitations (Census villages) are located and their distance from the nearest existing road are marked on the map. Demographic (population) and infrastructure data (socio-economic functions or facilities such as education center, health center, etc) in the habitation are also collected with the habitation data. The habitation data of Tamenglong district is enclosed as Appendix-A.

2.3.1. Road Inventory data

A comprehensive inventory of all rural roads including National Highways (NHs), State Highways (SHs), Major District Roads (MDRs), Other District roads (ODRs) and Village roads (VRs), road geometrics, road pavement condition, etc are also prepared at the block level and transferred on the database.

2.3.2. Map Data

Many different types of maps may be used at the different stages of the route layout, selection, and alignment process such as political/administrative boundaries, land use, topography, etc. The use of maps, overlaying maps with graphics, merging maps with non-graphic data and perform spatial analysis on various layers of information at any geographic point to enhance and support while making decisions or while replying to queries is one of the important fields strongly supported by GIS. A digitized map of Manipur based on the Survey of India Map (1:50,000) is used in the present work. The data collected at block level are transferred on the base map prepared incorporating all the information such as habitation location and road locations, alignment and their conditions.

2.4. Geographic Information System (GIS)

A Geographic information System (GIS) has an integrated system designed to collect, manage, and manipulate information in a spatial context. GIS products use a GIS data model called the georelational model which organises the attribute data in a series of layers that are referenced to the geographic features including polygons, lines, points and nodes. Most GIS follow this approach, and the key aspect of the model is the way in which attribute data are kept separate from the geographic information features. GIS products provide tools to manage the procedures that link spatial and attribute data. The usefulness of different GIS products for transportation applications is primarily determined by the manner in which these products do the linking of spatial data and attribute data and their effectiveness in managing the topological relationships. Some GISs are good at routing, whereas others manage attribute data better for building highway inventories.

With the rapid advancement in both computer hardware and its applications, spatial information are gathered and processed much more efficiently and quickly, based on technologies such as analytical and digital photogrammetry, global positioning systems (GPS) and satellite remote sensing. Manual drafting procedures are replaced by automated drafting and map production technologies from large GIS data thus allowing to model the real world in a much more structured fashion using the structured and spatial data. It is now possible to geographically reference critical data generated by government and private enterprises and also to query large amounts of spatially integrated data using information modelling and management techniques across multiple departments and users and thereby sharing the common elements. The result is that there is a rapid growth in the production and manipulation of geographic information, to the extent that many organizations can fulfill their production and operational goals only through the use of geographic information systems (GISs).

2.5. GIS in Transportation Planning

Widespread use of Geographic Information Systems in Transportation (GIS-T) planning is largely due to the legislation and enforcement of the two mandatory acts. viz. i). Intermodel Surface Transport Efficiency Act (ISTEA) of 1991, ii). the Clean air Act Amendments of 1990 with a view to the development of transportation programs to reduce traffic impacts. The growing interest in GIS-T is further encouraged by the requirements of Federal and State programs (by modelers and planners) to consider more consistent methods of data integration and display. The mission of Geographic Information Systems in Transportation (GIS-T) is to develop a single computer graphics environment that can provide the data modelling structure that has full topology for the GIS and flexible connectivity for network modelling. The capability of GIS to provide the uniform environment to integrate the data for numerous planning purposes which permits use of the spatially referenced data in many other applications is another advantage that adds value to the data and to the planning process (Sutton, 1996).

Sadek *et al* (2000) developed an integrated computerised approach for the assessment of potential highway layouts and demonstrates the merits and potential of GIS in automating route layout. Alphandopoulous *et al* (1995) developed a GIS model for travel demand forecasting and tested alternative schemes for transport infrastructure development and applied his model to Budapest city. Zura and Lipar (1995) used GIS spatial analysis to locate the corridor with the least environmental impact between origin and destination, defined in terms of population, fauna, flora, soil, water, air and climate. Kastelic and Zura (1992) developed a GIS model for selecting the least risk route in the transportation of hazardous materials and identifies an optimal path based on existing road network geometry and characteristics (road width, radius and slope) and the class of the hazardous materials to be transported. Sadek *et al* (2000) uses a GIS platform which incorporates the main digital data needed for evaluating route layouts in a computer based approach for a proposed highway layout assessment in the south of the city of Beirut, Lebanon. Sadek's modelling packages are specifically written codes with the GIS packages ARC/INFO and ArcVIEW.

Simkowitz (1990) presented results of the research conducted by Caliper Corporation on integrating GIS technology and transportation models. His approach involves two steps. The first is exploration of data required for various transportation models. The second step involves the collection and comparison of the content and structure of a transportation organization's databases with that required by various model types.

Gallimore *et al* (1992) use the geographic information system-transportation package, TransCAD to conduct an analysis for Charlotte, North Carolina area by merging data from a variety of sources and simulating the network with a doubly constrained gravity model technique. The study involves the existing traffic counts to make a preliminary forecast of the traffic, identification of several corridors by using another procedure called LINDSAT imagery. This analysis reveals another example of the use of GIS based packages in transportation planning and analysis which has altered the scale, scope, methodology of analysis and with that the relative power of planning organisations. It also shows that smaller cities or towns that had been analysed individually earlier can now be integrated into larger areas for analysis called super-regions.

Importance is given only to scientific and economic planning and management of rural roads in India in the last decade. GIS based database are developed and used for the Model Master Plan of Rural Roads. Some of the new projects that were taken up during the last few years in India are a). "Preparation of Model Master Plan for Rural Roads for Nagaon District, Assam (April, 2000)", b). "Project Preparation of Rural roads for 37 Districts of Bihar (April, 2000)", c). "Project preparation of Rural Roads for 18 Districts of Jharkhand, (April 2000)", d). "Plan for Roads in 14 districts in Kerala (June 2000 to February 2001)" (HRR, 2001).

Many applications of geographic information systems that have been implemented in the transportation field are mainly in the management of urban transport infrastructure and the assessment of road and traffic impact on the environment. The adaptation of GIS for transportation applications bears upon a number of areas. However, little is known about the application of GIS in the area of rural road planning. Applications in transportation planning, management and engineering utilize the available GIS technologies in various ways that involve the collection and analysis of required data. The capabilities of GIS in the Transportation field will permit the assimilation, integration, and coherent display of data collected and stored by the separate divisions within a highway agency (Vonderohe *et al*, 1993). For effective implementation of GIS techniques in rural road planning, a systematic and detailed computerized geo-spatial database is required. The database should be constructed from various secondary and primary sources of information available at block and district levels.

3. STUDY METHODOLOGY

3.1. Overview

The present study aims to develop appropriate models for optimum rural road planning by implementing the guidelines laid down in the Pradhan Mantri Gram Sadak Yojana (PMGSY) while providing accessibility to the various villages. The objective of the PMGSY is to provide road connectivity, through good all-weather roads to all rural habitations with a population more than i) 250 in hilly/desert areas, and ii) 500 in plain areas, by the year 2007. The developed model will enable to plan a network of rural roads with maximum social benefits, that is, the proposed network shall maximize population served per km length. The optimum rural road network can be represented graphically using GIS techniques by interfacing the model outputs with a GIS software, ArcInfo/ArcView.

Generally, planning of rural roads is done in a district level considering a district as a unit of planning. Since data collection and obtaining approval of local bodies is an important factor in formulating a master plan for rural roads, planning can be conveniently done in the middle level of administrative unit, i.e., Block or Mandal. The district level planning will also make implementation, monitoring and coordination of the project more effective and efficient. A district consists of a number of blocks or mandals with villages or inhabitants, for which connectivity with the nearest district-block head quarter, market centres or existing highways is to be provided. In the present study planning is done at the block level within a district so that the network planned and developed in the block and then to district levels will ultimately ensure the entire planning of rural roads in a State/Union Territory.

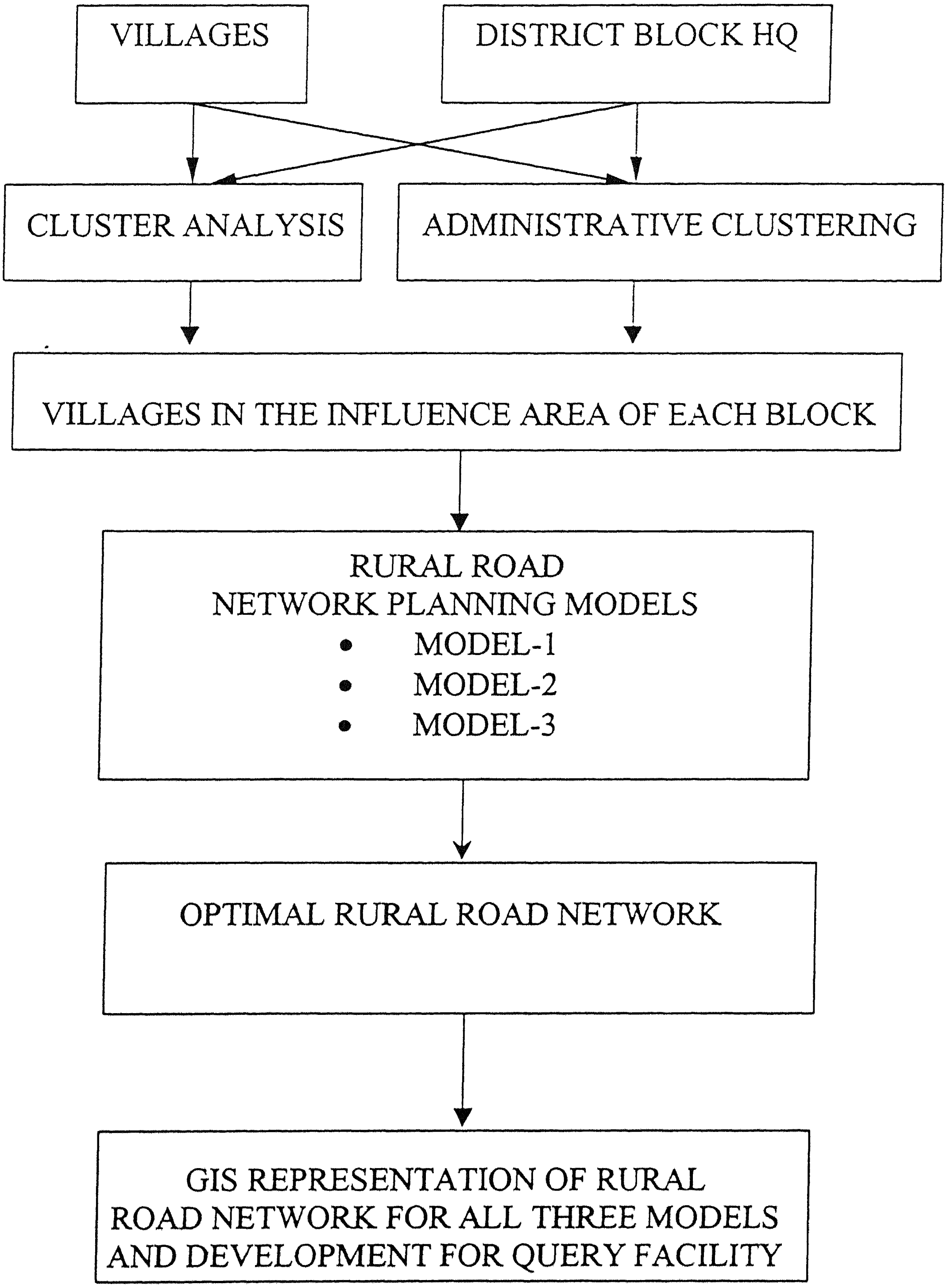

Fig. 3.1. Study Methodology

The methodology of the present work can be explained with the block diagram shown in Fig 3.1. Here planning is done in the middle level of administration, i.e., at the Block or Mandal level. First, the influence areas of the blocks in a district are identified. The villages situated within the influence area of the district-block are identified and clubbed together for providing connectivity from that district-block. This process is shown in level-1 and level-2 in Fig 3.1.

3.2. Delineation of Influence Area for Blocks

The identification of influence area of a district block, in that matter, the clustering of villages under a block can be done in either of the two ways as shown in level-2, Fig. 3.1. i) using the existing administrative boundaries or ii) the clustering with a suitable technique such as "minimum distance to means classification technique" adopted in the present work.

The administrative boundaries are meant for efficient and smooth administering of law and order and effective functioning of public distribution systems such as distribution of essential commodities, provision of basic services like health and education in every nook and corner of the district. Data collection for planning, consequently, rural road planning becomes a little difficult in block level planning when jurisdiction of established administrative block is very far from the district block. There are instances of existing administrative boundaries where effective administering of law and order and distribution of essential commodities and basic services to the inhabitants under its jurisdiction fails considerably. In fact, remote villages from the district block are not provided with any of the above objectives of law and order, basic services, essential commodities etc. An attempt to get an economic and better planning and also provision of basic services is made by clustering those remote villages under the administrative jurisdiction of a district block to that of other closer neighboring district blocks. This necessitates the clustering of villages or inhabitants based on a suitable clustering technique like the criterion of proximity to district blocks and checking which of the two is more effective.

3.2.1. Cluster Analysis

According to Fukunaga, pattern recognition consists of two parts: feature selection and classifier design. Most pattern recognition models are based on finding statistical or geometrical properties of substructures in the data. Two of the key concepts for describing geometry are angle and distance. For vectors $\mathbf{x}, \mathbf{v} \in \Re^{p}$, the functions $\langle\ \rangle_A : \Re^{p} \mathrm{x} \Re^{p} \rightarrow \Re$, $\|\ \|_A : \Re^{p} \rightarrow \Re^{T}$ and $\delta_A : \Re^{p} \mathrm{x} \Re^{p} \rightarrow \Re^{T}$ are the inner product (dot product, scalar product), norm (length) and norm metric (distance) induced on $\Re^{p}$ by weight matrix A.

$$\langle \mathbf{x}, \mathbf{v} \rangle_A = \mathbf{x}^T A \mathbf{v} \tag{3.1.1}$$

$$\|\mathbf{x}\|_A = \sqrt{\langle \mathbf{x}, \mathbf{x} \rangle_A} = \sqrt{\mathbf{x}^T A \mathbf{x}} \tag{3.1.2}$$

$$\delta_A(\mathbf{x} - \mathbf{v}) = \|\mathbf{x} - \mathbf{v}\|_A = \sqrt{(\mathbf{x} - \mathbf{v})^T A (\mathbf{x} - \mathbf{v})} \tag{3.1.3}$$

Equation (3.1.3) defines an infinite family of inner product induced distances, the most important of which is

$$\|\mathbf{x} - \mathbf{v}\|_I = \sqrt{(\mathbf{x} - \mathbf{v})^T I_p (\mathbf{x} - \mathbf{v})} \qquad \text{Euclidean distance,} \quad A = I_p \quad (3.1.4)$$

In (3.1.4) I_p is the *pxp* identity matrix and can be dropped. Rewriting in a simple form, we have,

$$\|\mathbf{x} - \mathbf{v}\| = \left(\sum_{i=1}^{p} |x_i - v_i| \right)^{\frac{1}{2}} \tag{3.1.5}$$

Hence a classifier is any function $\mathbf{D}:\Re^p \to N_{pc}$. The value $\mathbf{y}=\mathbf{D}(\mathbf{z})$ is the label vector for Z in $\Re^p$. $\mathbf{D}$ is a crisp classifier if $\mathbf{D}(\Re^p)=N_{hc}$, otherwise, the classifier is fuzzy or probabilistic or possibilistic N_{pc}. Designing a classifier simply means finding the parameters of a "good" **D**. This can be done with data, or it might be done by an expert without data. If the data are labeled, finding D is called *"Supervised Learning"*, otherwise the problem is "Unsupervised Learning". The terms supervised and unsupervised learning are used to specifically connote the use of labeled or unlabeled data (Bezdek, 1999).

Various supervised classification algorithms may be used to assign an unknown point (village) to one of a number of district-blocks (clusters or classes). The clustering problem is not well defined unless the resulting classes of samples are required to exhibit certain properties. The choice of properties or, equivalently, the definition of a cluster, is fundamental issue in the clustering problem. Given a suitable definition of a cluster, it is possible to distinguish between good and bad classifications of samples (Fukunaga, 1972). The choice of a particular classifier or decision rule depends on the nature of the input data and the desired output. A simple and commonly used classifier method is the minimum distance to means classification algorithm.

3.2.2. Minimum Distance to Means Classification Technique

This decision rule is computationally simple and commonly used and gives result in classification accuracy comparable to other computationally intensive algorithms, such as the maximum likelihood algorithm (Jensen, 1996). If there are "*k*" clusters, that is, if the number of clusters is known beforehand, to perform a minimum distance classification, a program must calculate the distance D_{ab} to each mean vector from each unknown pixel (the inhabitants or villages around the

centroids in our case). It is possible to calculate distance using Euclidean distance D_{ab} based on the Pythagorean theorem or "round the block" distance measures. The Euclidean distance is used in this present study and is given in relation (3.1.6):

Euclidean Distance: $$D_{AB} = \sqrt{(x_a - x_b)^2 + (y_a - y_b)^2} \tag{3.1.6}$$

Round the block Distance: $$D_{AB} = \sum_{i}^{n} |a_i - b_i| \tag{3.1.7}$$

The cluster analysis employed in the present work is based on the minimum distance to means classification technique in which Euclidean distance from a village to the centroids is used as the criterion for the classification or clustering of villages into groups or clusters or classes. The clustering of villages to a centroid, or district block is done as follows:

1. Read "n" number of villages in the district, population;
2. Read "m" number of centroids (block-HQ) in the district, and population;
3. Read x[i] and y[i] coordinates for the "n" villages and xc[j], yc[j] of the "m" centroids, $\forall i, \forall j$;
4. Calculate the Euclidean distance of a village from a centroid using the formula: dis[i][j] = sqrt[pow((x[i_n]-xc[j_m])),2) + pow((y[i_n]-yc[j_m])),2]; $\forall i, \forall j$
5. Calculate minimum distance, dis[i][j] of each and every village from each centroid, $\forall i, \forall j$
6. Assign the block-id to the village for which distance of the village from the centroid is the least
7. Generate villages under each blocks,

3.3. Rural Road Network Planning Models

It is proposed to formulate models to generate the optimal rural road network. The road links in the rural road network will have low volume of traffic and the objective is to provide better accessibility to the villages so as to boost the economic activities and provide basic services to the villages. The network to be developed for a block should minimize the construction cost, which is dependent upon the total road length developed in the network. It is, therefore, desirable to develop a network that has a minimum road length and at the same time provide accessibility to the adjoining villages and district block. As the available data is only that of population, it is appropriate to identify the network of rural roads that maximizes the population served per km length of the road developed. Three following heuristic network models are formulated:

a) **Model-1, Direct Connectivity of District Block and Villages,**
b) **Model-2, Road Length Threshold Criteria,** and
c) **Model-3, Threshold Road Length and Population Criteria.**

The first model provides direct connectivity with the district block and every village. This model will ensure faster and easier accessibility to district block from the villages under the influence area of the respective district-block. The inter-village accessibility may be inconvenient, as it has to pass through the district block, for every village, to access any other village in the cluster. The second model identifies the farthest village from the district block and computes the shortest distance in between them and this value is used as the threshold distance. Any of the path length developed here is equal to or less than this threshold distance. Here accessibility from some remote villages to district block may take a little more time as the route passes through other villages in between, as there is no direct accessibility. However, inter-village accessibility will be relatively better. The road

developed also will be shorter than the one in model-1. In the third model, the farthest village from the district block is identified first, and the shortest path between the district-block and the farthest village in the block is used as the threshold distance. The routes always originate from the district block and ends to a village away from the block depending on the location of the village. The number of villages connected in a route will be dependent upon the position of the villages from the centroid. The farthest village from the block is picked up and treated as the starting point of the first route in the network. The network extends from the farthest point towards the district-block by connecting with a set of adjoining villages near to it. The route goes on extending till it reaches the district block and connects villages in between by meandering away from the shortest path. Similarly other routes start from the farthest village among the unconnected villages and goes on extending till a threshold is reached or there is no village to be connected.

3.3.1. Description of the Models

The descriptions of the formulated three heuristic models are given in the following three sections.

3.3.1.0. Model -1: Direct Connectivity of District Block and Villages

Model-1 gives a simple and basic road network by connecting each and every village with the district-block. All the routes are generated from the district block towards the villages by connecting one village at a time thus providing good accessibility from villages to the district-block. The road length developed will be huge, inter-village accessibility will be poor, as even two close and neighboring villages has to pass the district block to access each other thus moving round the way. This methodology can be illustrated with the block diagram shown in Fig. 3.2.

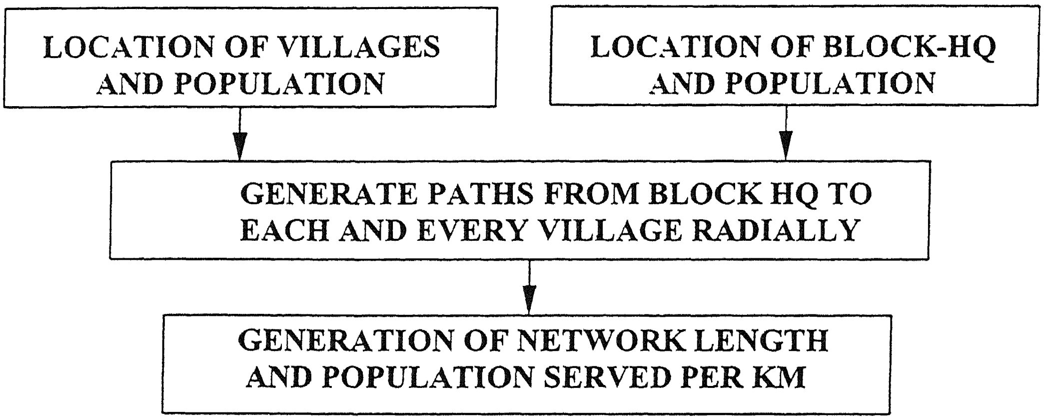

Fig.3.2. Block Diagram, Model-1

Connectivity of the villages in this model shall be done in the following manner:

1. Identify the villages under the influence area of a district block (centroid),
2. Provide connectivity from the centroid to each and every village under the influence area of the district block,
3. Compute the Euclidean distance between the centroid and each and every village and read the population of each village using relation (3.3.1),

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \qquad (3.3.1)$$

in which,

x_i, y_i = coordinates of the i^{th} village which is treated as the centroid,
or block and
x_j, y_j = coordinates of the j^{th} village,

4. Calculate the sum of all the distances obtained in (3) above and total population of all the villages including the district block,

5. The population served per km length of the road network developed is computed from relation (3.3.2)

$$Population\ served\ per\ km = \frac{\sum_{i=1}^{i=n-1} pi}{\sum_{i=1}^{i=n-1} length(i, i+i)} \qquad (3.3.2)$$

where

p_i = population of the ith village,
n = number of villages

This is a very simple method and the population served per km length of the road network is calculated by computing the total radial distance of all the links and the population of all the villages using relation (3.3.2).

3.3.1.1. Model -2: Road length Threshold Criteria

The model is an improved version of Model-1. Here road length developed will be shorter and the accessibility to inter-villages will be improved. The location of routes is based on the distance criteria only. The roads are generated from the district block and extend farther away outwards to the villages in the periphery till the path length reaches a threshold length. When a path crosses or reaches the threshold distance, a new path immediately starts from the nearest unconnected village from the district village. The process goes on till there is no unconnected village. The block diagram representing Model-2 is shown in Fig. 3.3.

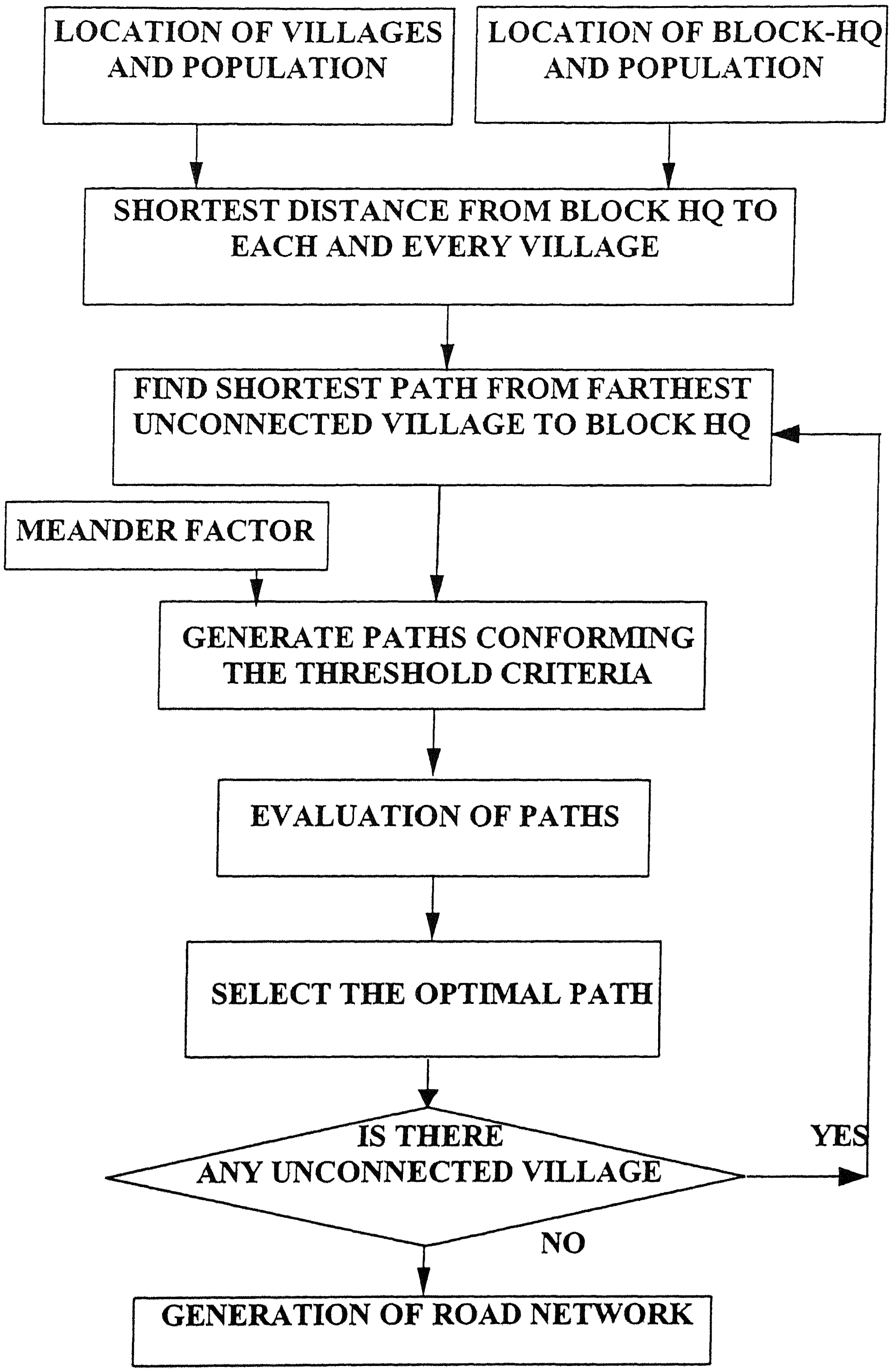

Fig. 3.3. Block Diagram, Model-2

Connectivity of the villages in this method will be done in the following manner:

1. Identify the villages under the influence area of the district block and number the villages sequentially from 2 through n where n is the number of the last village in the cluster, while the district block is numbered 1 itself.

2. Select the nearest village from the district-block (node-1), and then provide the nearest village (say node-x) a road link from the district-block, thus establishing the first link of the network. The distance of this link and population of both the nodes is added to the variables total distance and total population.

3. Select from the unconnected nodes, (say node-y), the nearest village from node-x, which was the nearest village from district-block in step-2.

4. Compute the Euclidean distance between the pair of villages connected in (step-3) and read also the population of the village or under process:

5.i.) if the distance between the node under consideration for connectivity and the district block head quarter does not fall below a minimum threshold distance;

5.ii) **and** if the total distance obtained including the present link do not cross 50% of the maximum threshold distance;

5.iii) **or**, if the total distance of the developed road network does not cross the maximum threshold distance.

The node under consideration is provided with a link. The distance of this road link and population of the node under consideration is added to the total population and total distance.

6. If the criteria in Step 5.i and 5.ii or Step 5.iii are violated a new route or path begins. Substitute node-x by node-y and the nearest unconnected node is selected and it is assigned to node-y. Steps 3 through 5 are repeated starting from the nearest unconnected village from the district block until all the villages are provided with a road network connectivity.

The population served per km length of the road network is derived using relation (3.3.2) and is used for determining the optimum model. The criterion used being i) accessibility of centroid from any village via intermediate villages should not be more than half the direct radial distance between the centroid and the village under consideration **or** ii). no village should be provided connectivity with too large meandering, i.e., the maximum distance through which a village can be accessed through intermediate villages should not be more than the threshold distance.

The process of providing connectivity to the villages using Model-2 can be illustrated by selecting a district block with eight villages shown in Table 3.1. The villages are numbered from 1 through 9 where the numbering starts from the block. The details of the x-coordinate, y-coordinate, population and village-name are given in Table 3.2. The distances between each and every node are calculated using the Euclidean distance formula: $D_{AB} = \sqrt{(x_a - x_b)^2 + (y_a - y_b)^2}$

The distances calculated are tabulated in Table-3.2. The shortest path from the block to the farthest village constitutes the links 5-4-3-1 and distance of this shortest path =2.92+1.47+2.23 = 6.62 km

Table-3.1. Details of villages in a Typical block

Node No.	x-coordinate	y-coordinate	Population	Name of village
1	93.37842	25.11623	**1181**	Tousem Khullen
2	93.40568	25.16564	**412**	Phoklong
3	93.33913	25.06451	**591**	Old mandu
4	93.31577	25.02975	**307**	Kandihang
5	93.28646	24.95166	**455**	Aben
6	93.4322	25.05803	**415**	Namtiram
7	93.45237	25.10286	**345**	Phelong
8	93.48879	25.18542	**316**	Inem
9	93.48603	25.15685	**472**	Taningjam

Table 3.2. Distance between pair of villages

Distance From	**Dt-Block (Node1)**	**Node2**	**Node 3**	**Node 4**	**Node 5**	**Node 6**	**Node 7**	**Node8**	**Node9**
Dt-Block	0	1. 9751	2.2273	3.7375	6.5982	2.7735	2.6303	4.5594	4.0258
Node2	1.9751	0	4.2372	5.7028	8.5732	3.8791	2.7384	2.9903	2.8291
Node3	2.2273	4.2372	0	1.4657	4.3587	3.2654	4.1846	6.7341	6.0730
Node4	3.7375	5.7028	1.4657	0	2.9194	4.1933	5.4226	8.1459	7.4363
Node5	6.5982	8.5732	4.3587	2.9194	0	6.3149	7.8565	10.8207	10.0183
Node6	2.7735	3.8791	3.2654	4.1934	6.3149	0	1.7206	4.8788	3.9387
Node7	2.6303	2.7384	4.1846	5.4226	7.8565	1.7206	0	3.1583	2.2269
Node8	4.5594	2.9902	6.7341	8.1459	10.8207	4.8788	3.1583	0	1.0046
Node9	4.0258	2.8291	6.0730	7.4363	10.0183	3.9387	2.2269	1.0046	0

Distance matrix for the cluster of villages consisting of village-1 through village- 9 under the influence area of the district block (node-1) is constructed, (Table 3.2.). Then, the nearest village (village-2) to the district block is selected. Village-2 is provided with a road link from the district-block, thus establishing the first link of the network. The distance between village-1 and village-2, 1.97 km is stored at a variable " t-dis ". For the next node, the nearest village to village-2, i.e., village-7 is selected. The link length or distance between node-2 and node-7 is 2.74 km. This distance is added to the previous value of t-dis (4.71 km) and is compared with the threshold assumed, (i.e., *th-dist=6.62 x 1.25 = 8. 28* km). Also, the distance between the current village under processing and district block, x_{cn} *(=2.63 km)* is checked. If x_{cn} is less than 50% of *t-dis (0.5*4.71 km=2.36),* node-7 will not be provided with a connectivity from node-2. However, x_{cn} is greater than 2.36 km, and this is less than "*th-dist*" of 8.28 km, hence, a link is provided from village-2 to village-7 thus making a path from 1-2-7. In other words, when and only when the distance between the centroid and the village (x_{cn}=*2.63* km) under processing is greater than the updated value of 50% of *t-dis* (*2.36 km*), or the updated value of *t-dis (4.71 km) is less than* the *th-dist* (8.28 km), village-7 is provided with a link from village-2. The population of village-7 is read and the *t-pop and t-dis* variables are updated. The next nearest village from village-7 is village-9, situated at a distance of 2.23 km. The total distance *t-dis* now becomes 6.94 km which still does not exceed the threshold distance, but is less than half the radial distance between village-9 and centroid (i.e., *0.5 x 6.94 =3.47 km* > 4.03 *km*), hence the path ends at the previous village-7.

Similarly the other villages are also provided with a link in path "p_i" after duly checking the updated value of " *t-dis*" with the threshold values. Every time the calculated distance violates the threshold value of the distances, a new path "p_{i+1}" begins from the district-block and connection of links carried out in the same manner till all the nodes are provided with a connectivity from the district-block. The first path p_1 has the nodes 1,2,7 and links ***1-2-7,*** for the second path p_2, the

nodes are ***1,3,4,5.*** The links of path-2 consists of ***1-3-4-5.*** The nodes and links of the 3rd path are 1,6,9,8 and 1-6-9-8 respectively (Fig 3.4). The total distance of all these paths in the network is given by *t-dis* and works out to 19.09 km while the total population served is 4484. The population served per km length of the road network is found out and it works out to 234.

The threshold value can be changed by using the relation ***"th-dist = shortest distance (s-distance) between the centroid and the farthest village times the meander factor, mf"***. A sensitivity analysis is done with meandering factors, "mf" of 1.25, 1.50 1,75 and 2.00 and the various values of population served per km length of the road length is maximized. The values obtained in the sensitivity analysis are given in table 3.3. *From the table is seen that there is no change in the population served per km length for increase in the threshold distance.* Hence, the network with paths a). 1-2-7, b). 1-3-4-5, c). 1-6-9-8 (Fig. 3.3) with a total road length of 19.10 km serving a population of 4484 and population served per km length of 234 is suggested for this block with 8 villages. The suggested threshold value and paths for the proposed network is marked with 1 against the *Remark* column.

3.3.1.2. Model -3: Threshold Road Length and Population Criteria

The farthest village from the district block is first identified. Starting from the farthest unconnected village, the model generates various alternative paths from the farthest village to the district block. These alternative paths are then evaluated based on the criteria of population served per km length of road developed and the optimum path is identified. The path of an alternative is dependent upon the threshold limits defined in terms of meander factors away from the shortest path. The block diagram representing this model is given in Fig. 3.5.

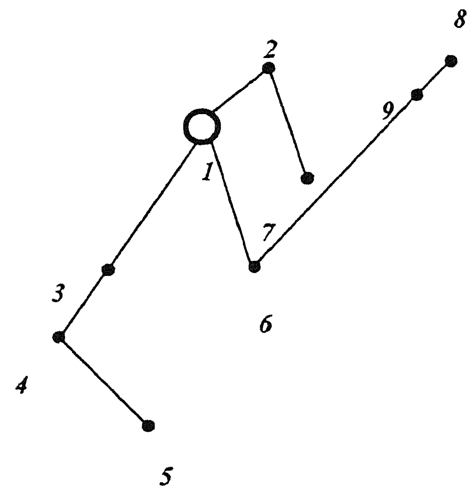

Fig. 3.4. A Typical Model-2 Road Network

Table 3.3. Details of Typical Model-2 Paths

Cycle N0.	Threshold distance (in mtr)	Road length (in mtr)	Population served	Population served/km	Remark
1	*8322.94*	*19088.6*	*4484*	*234.905*	*1*
paths: a.	1 2 7	4713.48			
b.	1 3 4 5	6658.36			
c.	1 6 9 8	7716.75			
2	*9987.53*	*19088.6*	*4484*	*234.905*	*0*
paths: a.	1 2 7	4713.48			
b.	1 3 4 5	6658.36			
c.	1 6 9 8	7716.75			
3	*11652.1*	*19088.6*	*4484*	*234.905*	*0*
paths: a.	1 2 7	4713.48			
b.	1 3 4 5	6658.36			
c.	1 6 9 8	7716.75			
4	*13316.7*	*19088.6*	*4484*	*234.905*	*0*
paths: a.	1 2 7	4713.48			
b.	1 3 4 5	6658.36			
c.	1 6 9 8	7716.75			

Connectivity of the villages in this method will be done in the following manner:

1. The first step in this model essentially consists of identification of the farthest village from the district block and determination of the shortest path between the farthest village in the block under consideration with respect to the district block.

2. Then considering villages close to the shortest path, and meandering from the shortest path a set of alternative paths are generated.

3. All the generated alternative paths are evaluated. The statistics for the analysis is based on the population served per km length of the road network developed. The population served per km length of the road network can be obtained from the relation in (3.3.2):

These alternative paths will have path lengths greater than the shortest path determined in step-1 above. However, this set of paths will be serving more people as the number of villages is increased while meandering from the shortest path. The length of a generated alternative path is subject to the constraints of a threshold length that depends on a factor called the "meander-factor". The threshold length is the product of the shortest distance between the district block and the farthest village and the meandering factor. A meander factor of 1.25, 1.50, 1.75 and 2.00 are considered for sensitivity analysis of the road network developed. The generation of the alternative path ensures that there is no backtracking.

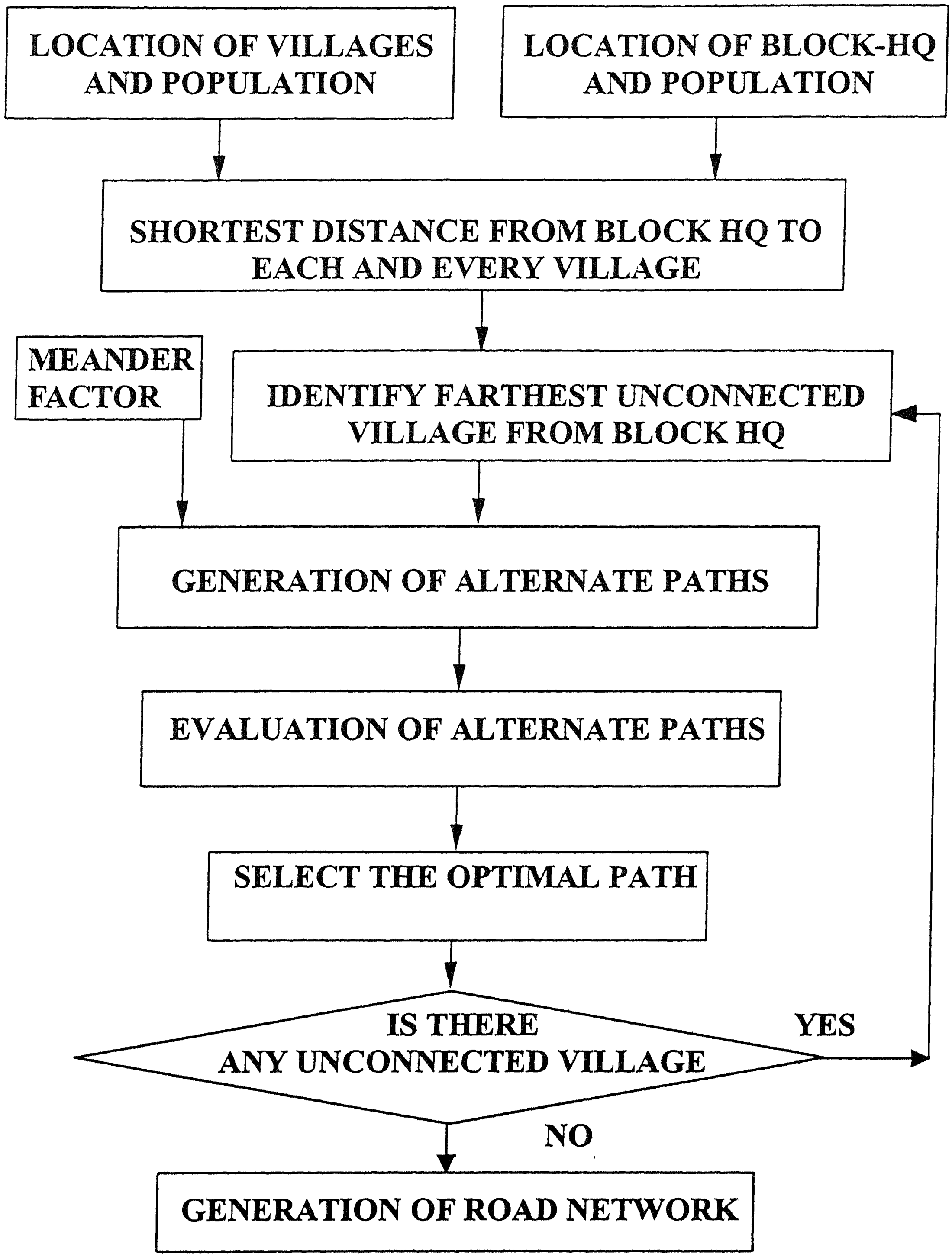

Fig. 3.5. Block Diagram, Model-3

The criteria in (3.3.2) can be adopted to determine the optimum path. However, the main drawback of this criterion is that it accounts for only the total length and total population served. An improvement over the above criteria can be achieved in terms of population-km per km length. This criterion will consider the flow over the different links, which is not accounted in the above criterion. The population-km is the product of various village population and distance to the district block. If the length is more, than the population-km will also be higher. A further improved version in this model can be achieved by not considering the actual distance along the path between the shortest distance from the village to the district block.

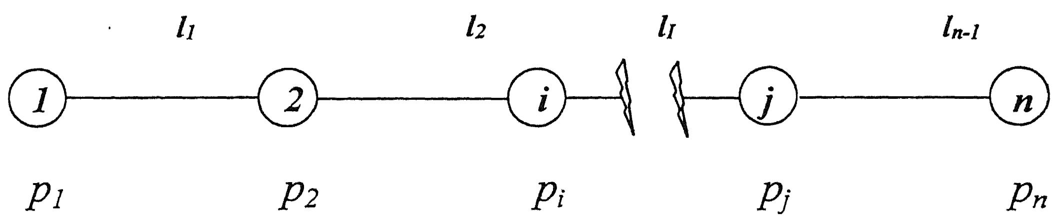

Fig. 3.6. Typical links and nodes in a path

If there be "n" villages along a path, population-km can be estimated as $p_i * s_{di}$

where p_i = Population of the i^{th} village,

s_{d_i} = Shortest distance between the i^{th} village and district block,

L = Total length of the path.

The evaluation criteria select that path which maximizes $\sum_{\forall i} p_i \cdot s_{d_i} / L$;

This criterion considers the population of the villages, shortest-distance from the village under consideration to the district block and also the total length of the route.

4. The optimal path among the alternative paths generated is selected.

5. The procedures in steps 2 through 4 are repeated till the road network connects all the villages in the district.

Consider the same block with eight villages in Table-3.2. for illustration of Model-3. Here the district block is numbered 9, i.e., the district block is coined the last or the nth number. The following steps explain this methodology.

Step 1 – The population of all the villages falling under the district-block is added and calculated as demand of a particular district-block. Then farthest village (node-*5*) in the cluster under the district block (node-*9*) is identified and marked for providing the road network from the district-block. The shortest path from district block, link 9-5 gives one alternative path. Other links connecting the adjoining villages constitutes other two paths in the set of alternative paths. A set of feasible alternative routes, 5-3-9 and 5-4-9 from (node-**5**) to (node-*9*) is considered.

Step 2 - Following statistics are estimated for each alternative path

- Road length
- Population served along the route
- Population served per km
- Population served - km per km
- Route Utilization factor

Step 3 - An alternative that maximizes the Population-km/km is taken as the optimal route. The route in Sl.No.2 (Table-3.5.) with the maximum Population served per km of 4345 and corresponding Population-km/km of 655 is provided with a road network for accessibility to the villages ***5*, *3*** and ***9*.**

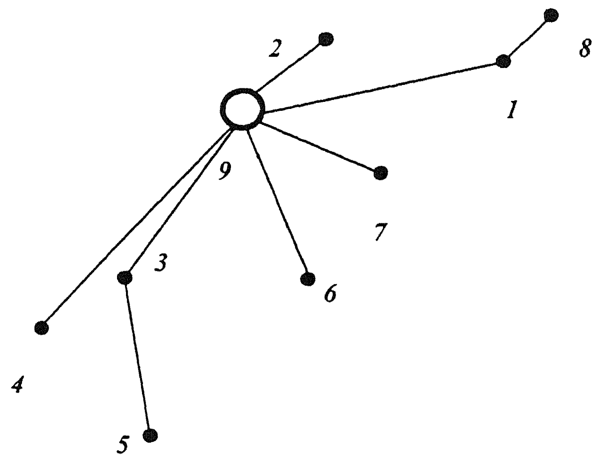

Fig 3.7. A Typical Model - 3 Road Network

Table 3.4. Details of a typical set of Model-3 Alternative paths

Sl. No.	No of nodes	Sequence of Nodes in a path	Length of path developed (in mtrs)
1	2	5 9	6598
2	3	5 3 9	6632
3	3	5 4 9	6656

Table 3.5. Statistics of first set of alternative paths, Model-3 Road Network

Sl. No.	Length of road (in mtr)	Population	Population served/km length of road	Utilization factor	Pop-km	Pop-km per km served
1	6598	455	69	1.000	3002	455
2	6632	1046	158	0.998	4345	655
3	6656	762	114	0.995	4149	623

Table 3.6. Details of a Typical set of Model-3 paths/routes

Sl. No.	No of nodes	Sequence of Nodes in a path	Length of the path developed (in mtrs)
a)	*1st path*		
1	2	5 9	6598
2	3	5 3 9	6632
3	3	5 4 9	6656
b)	*2nd path*		
1	2	8 9	4559
2	3	8 1 9	5031
3	3	8 2 9	4965
c)	*3rd path*		
1	2	4 9	3737
2	3	4 3 9	3739
d)	*4th path*		
1	2	6 9	2774
e)	*5th path*		
1	2	7 9	2630
f)	*6th path*		
1	2	2 9	1975

Step 4 - Procedures in step 1-3 are repeated till all villages in the cluster of the district-block are considered and a set of routes consisting of optimally generated routes for a particular district-block is obtained.

The various combinations of links in the 1^{st} set of paths and their nodes with population and road length are shown in Table 3.5. Similarly, other paths are also obtained. Table 3.6. gives the possible alternative paths generated for the whole block.

The effectiveness of clustering villages using Euclidean mean distance can be compared with the clustering of villages as existed under the administrative line based on the population served per km length of the network developed in either cases. The one that maximizes will be suggested for the proposed road network.

3.4. GIS Representation of Rural Road Network

The digitized map of the eight districts (Imphal East and Imphal West districts not separated) and outline maps of these eight districts of Manipur state are added as themes to the view menu of the Arc-View software and stored as a file for future reference and processing. The locations of the inhabitants are also plotted on this digitized map with respect to latitude and longitude (x-coordinate and y-coordinate). Points on the digitized map represent the inhabitations or villages. The nodes and links of the network obtained as outputs from the models are transformed as coordinates using a c^{++} program. A pair of x and y coordinates will represent a node and two successive x-coordinates and y-coordinates of a pair of nodes, a link. All the nodes and links of the network are transferred on the map through coordinates and pairs of corresponding coordinates so as to represent the links of the various roads in the network. Combinations of points and lines thus represent a road network.

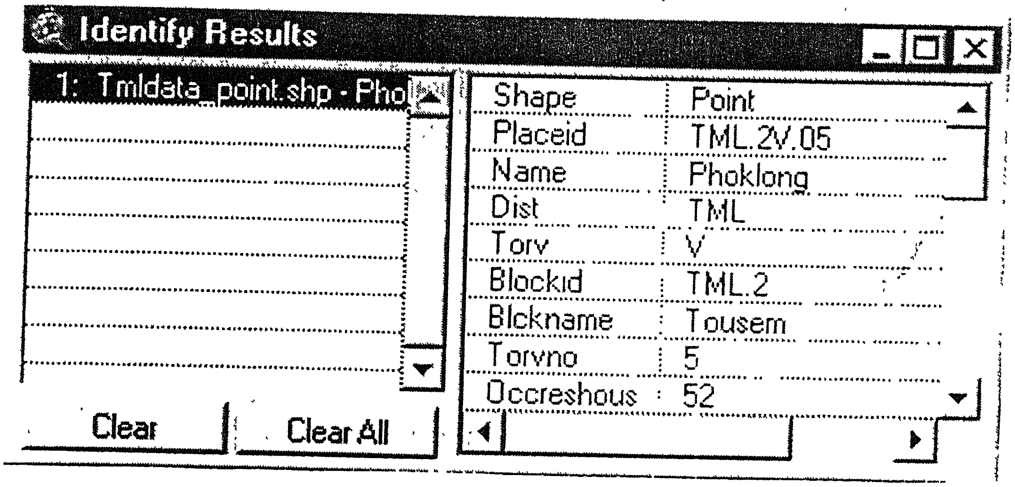

Fig. 3.8. A Typical GIS Query results of nodes in ArcView

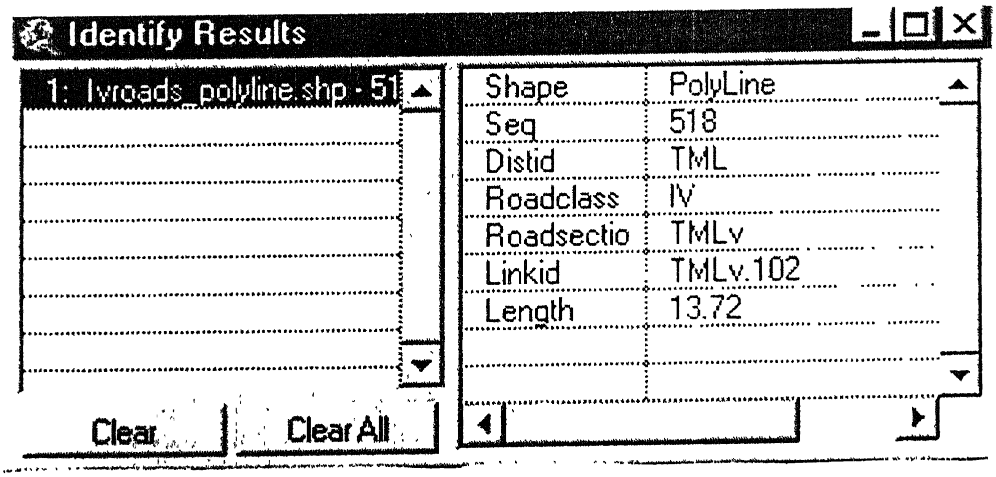

Fig. 3.9. A Typical GIS Query results of links in ArcView

The available query facility enables users to identify the details of the nodes available with the GIS database. The details of the inhabitants like village name, block-name, village population, distance from the nearest town etc. s available in the Main GIS database could be known using this query facility. Fig 3.8. shows such a typical pop up screen giving details of a node or village. Similar query on links provides the details of a link. Such as the link length, and link width. Fig. 3.9. shows a typical information available to such a query for a link. The query information can further be improved by incorporating other traffic characteristics such as link flows from input files through avenue script and integrating with the main GIS database. The link flow option is made inactive for the time being due to the lack of data.

3.5. Summary

Three heuristic network-planning models have been formulated in the course of the study to generate optimum rural road network planning. The data sets used for the models are obtained from two approaches - a) the available block and villages falling under the administrative jurisdiction, and b) block and villages falling under its influence area obtained from cluster analysis. These data sets are to be fed to the three formulated models to generate the optimum rural network at a block level of a district.

The first model, Model-1, "Direct Connectivity of District Block and Villages" uses an elementary and simple technique of connecting two points to generate links in which one of the two points is always the district block and the other one being any of the villages under the block. The network generated by this model will give direct connectivity from each village to the district block. The accessibility of the block from any of the villages is direct and convenient. The road length generated will be huge and the inter-village accessibility will be poor.

In Model-2, "Road Length Threshold Criteria", roads are generated from the district block towards the first nearest unconnected village and extend further to the next nearest unconnected village till a threshold limit is reached or all the villages are connected. The threshold limit adopted is the shortest distance between the farthest village and the district-block times a meander factor. Here distance between two nodes is used as the criterion for creating a link. Road length will be shorter and interconnectivity between villages will better. The network generated by this model can be proposed for implementation.

In the third model, "Threshold Road Length and Population Criteria", the roads are generated from the farthest unconnected villages towards the district-block. Each path has a set of alternative paths formed by connecting adjoining villages, thus meandering away from the shortest path. Due to the selection the roads to the district block will connect a number of villages. The optimum path from this set of alternative paths is selected for the network model. The process repeats till all the villages are provided with connectivity. The threshold limit adopted in this method is the same as that applied in Model-2. Here in addition to the distance, other village characteristics like population is used for determining the villages to be connected while creating a path. Model-3 is certainly an improved model over Model-2. The road network developed by this model can also be proposed for implementation. The networks developed from these three formulated models can be compared and the optimum and/or feasible road network could be selected.

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Fig. 4.1. Model Application Area, State of Manipur

4. THE STUDY AREA - STATE OF MANIPUR

4.1. Manipur

Tamenglong district, the area taken up for the pilot testing of the model is one of the districts of Manipur, a state in the northeastern region of India. Manipur is bounded by the states and country, Myanmar on the east and southeast, by Nagaland on the north, by Assam on the west and by Mizoram on the southwest (Fig. 4.1). The State covers an area of 22,327 square kms between Latitudes $23^0 32'$ N and $25^0 41'$N and Longitude $93^0 02'$ E and $94^{04} 7'$E. The population of the state as per the 1991 census is 1,837,149. Geographically Manipur is a landlocked state (Singh, 1997). The state is mainly linked with the rest of the country through the Imphal-Dimapur Road (National Highway No.39) and the Imphal-Jiribam Road (National Highway No. 53). The former connects Imphal with rail-head at Dimapur in Nagaland at a distance of about 215 kms and the latter connects Imphal with Silchar in Assam at a distance of about 225 kms. There is no seaport or waterways that could connect the state with the rest of the world. Manipur is connected by air via Aizawl, Jorhat, Guwahati, Slicker, Calcutta and Delhi. Topographically the state can be divided into three physical units, viz. the Manipur Valley, the Manipur Hills, and the Jiribam Basin, each having its own geographical personality. The capital of this tiny state, Imphal is centrally situated at an elevation of about 800 m above Mean Sea Level. The entire population is distributed in these three physical settings comprising 9 districts - 5 in the hill areas and 4 in the valley region. Out of the nine districts of Manipur, Tamenglong district is the most backward district and this backward district is taken up for the present study.

4.1.1. Hills

The hill districts are: Senapati (pop 2,08,406), Ukhrul (pop 1,09,275), Chandel (pop 71,014), Churachandpur (pop 1,76,184) and Tamenglong (pop 86,278). These five hill districts constitute about 90% of the total area of the state.

4.1.2. Valley

The valley area is contained in the four districts of Imphal (East pop 3,30,480) and (West pop 3,80,801), Thoubal (pop 2,93,958), and Bishnupur (pop 1,80,773). The Imphal Valley has an area of 1,843 sq km. The valley is surrounded by hills, which rise in places to 3,000 m above the MSL. Jiribam (395 sq km) is another smaller valley at or near sea level that lies on the western border between the Barak and Jiri rivers. The valleys comprise about 10% of the land area and houses to over two thirds of the people.

4.2. Road Network

In 1987 the total length of surfaced roads including National and State Highways, Major and Other District Roads and Inter-Village Roads was 4,279 km. The density of the road network in the state at the beginning of the 9th Five Year Plan was only 31.82 km per 100 sq. km. as against the all India standard of 62 km per 100 sq. km. The digitized road network GIS comprises the list of road sections of National Highways (NH) - black, State Highways (SH) - red, Major District Roads (MD - blue, and Other District Roads (OD) - green, some Inter-Village Roads (IV) - yellow. X and Y co-ordinates, altitude and trip distance as obtained from hand-held GPS, location of potential quarry sites (Johnson, 2001). The GIS database consists of several files of which the most important file, MAINroads table consists of the fields given in Table 4.1. In order to provide connectivity to all villages/inhabitation new roads will have to be constructed under BMS/PMGSY.

4.3. Towns and Villages

The total number of villages in Manipur state, as per 1991 Census of India, is 2180. The representation of villages in the GIS database is done based on allocating a Unique Identifier - PlaceID, e.g. TML.1V.12. Here, TML stands for the standard district abbreviation, Tamenglong, the pilot district. "1" is the number allocated to the development block in the Tamegnlong district. 'V' is used to designate village to the place ("T" for town) and "12" is the serial number allocated to the village in the appropriate census volume.

4.4. Study Area: Tamenglong District

Out of the nine districts in the state, Imphal district (undivided) is the most developed and Tamenglong is the most backward district of Manipur (Munindro, 2000). When compared to the other districts, Tamenglong lags behind the other districts in terms of development, road connectivity, basic amenities etc. Hence, Tamenglong district is chosen as the district for the present study. The present study aims at providing the road connectivity to villages with a population above 250 in Tamenglong, one of the hill districts of Manipur as per the guidelines of the Pradhan Mantri Gram Sadak Yojana.

Table 4.1 Details of fields "MAINroads" GIS database

- DIST - District
- CLASS - Class (NH, SH, MD, OD)
- RS - Road Section
- RSdesc - Road Section Description
- RSlength - Road Section - Length (as specified on the list of roads)
- RStype - Road Section - type of construction
- RScond - Road Section - condition of road (from PWD records)
- RSwidh - Road Section - road width
- LinkID
- NA - node number at start of link
- NB - node number at end of link
- LEN - Length of link derived from the GIS. (using function SphericalObjectLen)
- GPSlen - Length of Link derived from GPS outputs from a drive along the Road Section)
- Terrain - Type of Terrain
- Flow - Traffic Flow
- Capacity - Link Capacity
- Rwidth - Road Width (from Strip Plan Survey where available)

Tamenglong is located at the north-western boundary of the state. It is surrounded by Senapati district in the north, Churachandpur in the South and Cachar district of Assam in the west (Fig. 4.2). Tamenglong is entirely composed of hills, ranges and narrow valleys. Tamenglong HQ can be reached through Roadways. The district HQ, Tamenglong is 156 kms from Imphal.

The total area of Tamenglong district (4391 sq. kms) constitutes 19.7% of the total area of the state and the population of this district (86,278 as per 1991 census) constitutes 4.70% of the total population of the state. It has 4 district-blocks (Tousem, Tamei, Nungba and Tamenglong). There are 194 villages under these four district-blocks. Tousem block has 60 villages, Tamei has 30 villages, Nungba has 58 villages and Tamenglong has 46 villages. Out of the 194 villages, 73 villages are with population range below 200, while 62 are with a population range between 200 and 499, 55 with a range between 500 to 1499. There are two villages with population between 2000 and 4999 in Nungba Block and one village with the population range of 500 to 9999 in Tamenglong Block. 33% of the total villages are with population less than 200. There are altogether 109 villages with a population above 250 in this district. The particulars of Tamenglong district, block-wise distribution of villages based on population range and portion of the GIS database of Tamenglong district is given in Appendix-A. This GIS database is used as source of input data for the present work. However, coordinates of two villages, Ejeirong and Phaitol as available in the data do not fall within the district boundary, hence these two villages are excluded while planning and only 107 villages are considered.

5. ANALYSIS OF RESULTS

5.1. Model Application for Study Area

The models are tested first with a pilot district, Tamenglong and then applied to two districts, Bishnupur, and Churachandpur neighboring to the pilot district in Manipur. Census data is the source of the administrative data, i.e., district block with villages under its administrative umbrella. The cluster data, i.e., district block with villages under its influence area are obtained from the cluster analysis of administrative data. The cluster analysis output obtained from the administrative data set is shown in Table-5.1. The administrative data set is enclosed as "Appendix-B". To perform the sensibility analysis meander factors of 1.25, 1.50, 1.75 and 2.00 are used in Model-2 and Model-3. The population of the block, road length developed, the population served per km length at a particular meander factor is noted and these values are used for further analysis. The outputs obtained from the models using this administrative data set and cluster data set given in Table 5.1. are enclosed as "Appendix-C".

5.2. Analysis of Model Outputs for Pilot District, Tamenglong

The details of results obtained from the models using data of the pilot district are given in Tables 5.2 - 5.7. The road network developed in the pilot district using cluster analysis data by the models are shown in Fig. 5.1 - 5.3. The outputs of the models show that road network obtained through Model-1 gives the highest road length and that through Model-2, the shortest road length. The difference in the road length in the two models seems quite large as the number of villages increases. Model-3 road networks are having road lengths more than their counterparts in both cluster and administrative data. Road lengths developed through Model-2 and Model-3 seem quite comparable. The difference in margin is quite less when the block size is small. Model-2 seems to generate the best road network model as far as road length is considered.

Table 5.1. Cluster analysis output from Administrative data

Bl_No	X-coord	Y-coord	Vill_no		Block-Name
1	93.6754	25.1526	1330	2	Tamei
2	93.3784	25.1162	1181	27	Tousem
3	93.5080	25.0081	7733	48	Tamenglong
4	93.4262	24.7432	1245	81	Nungba

[Scale factor of map : 1 in = 35 kms]

Block Head Qtr No. [1]   No. of Villages = 30
Block Head Qtr No. [2]   No. of Villages = 9
Block Head Qtr No. [3]   No. of Villages = 32
Block Head Qtr No. [4]   No. of Villages = 36

Legend
V_No. : Village Number
A-Bl : Administrative Block
C-Bl : Current Block changed due to cluster analysis

nodes :
Block Head Qtr No. [1]   No. of Villages = 30

Sl.No.	x-coord	y-coord	popltn	V-No	A-Bl	C-Bl
1	93.76296	25.32162	1444	1	1	1
2	93.67543	25.15260	1330	2	1	1
3	93.72780	25.34450	1134	3	1	1
4	93.81861	25.40336	1028	4	1	1
5	93.69038	25.31183	901	5	1	1
6	93.67611	25.27146	871	6	1	1
7	93.77299	25.35278	802	7	1	1
8	93.79714	25.41481	793	8	1	1
9	93.71959	25.24086	790	9	1	1
10	93.67073	25.13384	759	10	1	1
11	93.75766	25.39246	681	11	1	1
12	93.75362	25.15952	680	12	1	1
13	93.69780	25.17400	585	14	1	1
14	93.66334	25.25262	577	15	1	1
15	93.64323	25.21095	521	16	1	1
16	93.62599	25.08578	430	17	1	1
17	93.69189	25.22387	411	18	1	1
18	93.78966	25.08721	389	19	1	1
19	93.58279	25.15359	347	20	1	1
20	93.62467	25.18425	326	21	1	1
21	93.73963	25.02660	315	23	1	1
22	93.68557	25.16760	304	24	1	1
23	93.70744	25.06770	294	25	1	1
24	93.64426	25.11360	286	26	1	1
25	93.54664	25.22371	676	30	1	2

26	93.56743	25.18751	443	38	1	2
27	93.56255	25.18389	408	43	1	2
28	93.63182	25.05285	713	58	1	3
29	93.67481	25.00945	585	59	1	3
30	93.76118	24.94002	320	72	1	3

nodes :
Block Head Qtr No. [2]   No. of Villages = 9

1	93.37842	25.11623	1181	27	2	2
2	93.33913	25.06451	591	32	2	2
3	93.48603	25.15685	472	36	2	2
4	93.28646	24.95166	445	37	2	2
5	93.43220	25.05803	415	41	2	2
6	93.40568	25.16564	412	42	2	2
7	93.45237	25.10286	345	44	2	2
8	93.48879	25.18542	316	46	2	2
9	93.31577	25.02975	307	47	2	2

nodes :
Block Head Qtr No. [3]   No. of Villages = 32

1	93.61609	25.04474	677	13	3	1
2	93.52799	25.13431	320	22	3	1
3	93.40430	24.99306	732	29	3	2
4	93.42392	25.03639	559	33	3	2
5	93.42018	25.01627	526	34	3	2
6	93.35369	24.92257	416	40	3	2
7	93.37014	24.95045	341	45	3	2
8	93.50797	25.00810	7733	48	3	3
9	93.67905	24.81927	1268	49	3	3
10	93.54878	24.85412	1147	50	3	3
11	93.49229	24.91279	1002	51	3	3
12	93.57031	24.97195	996	52	3	3
13	93.54096	25.05449	864	53	3	3
14	93.52326	25.02928	838	54	3	3
15	93.67322	24.88577	828	55	3	3
16	93.55735	24.88122	793	56	3	3
17	93.57389	24.93180	781	57	3	3
18	93.65541	24.98138	567	60	3	3
19	93.63061	24.93583	540	61	3	3
20	93.49460	24.93479	520	63	3	3
21	93.55275	24.92367	498	64	3	3
22	93.70369	24.92464	491	65	3	3
23	93.44297	24.88631	478	66	3	3
24	93.50436	25.07342	464	67	3	3
25	93.45033	24.89160	455	68	3	3
26	93.67731	24.87371	442	69	3	3

27	93.45188	24.96306	421	70	3	3
28	93.69136	24.87898	324	71	3	3
29	93.46858	24.94558	310	73	3	3
30	93.52297	24.91788	286	76	3	3
31	93.63022	24.84076	2230	79	3	4
32	93.58719	24.86430	555	90	3	4

nodes :

Block Head Qtr No. [4] No. of Villages = 36

1	93.29117	24.75432	958	28	4	2
2	93.33659	24.79109	666	31	4	2
3	93.36407	24.79925	479	35	4	2
4	93.26720	24.71571	438	39	4	2
5	93.44076	24.84863	537	62	4	3
6	93.47632	24.86663	306	74	4	3
7	93.46838	24.85512	295	75	4	3
8	93.55085	24.84751	260	77	4	3
9	93.52241	24.71481	2996	78	4	4
10	93.53488	24.76783	1315	80	4	4
11	93.42619	24.74321	1245	81	4	4
12	93.63603	24.71885	947	82	4	4
13	93.66937	24.66021	896	83	4	4
14	93.51010	24.78334	866	84	4	4
15	93.55642	24.63047	853	85	4	4
16	93.41309	24.65001	671	86	4	4
17	93.56473	24.69691	665	87	4	4
18	93.23651	24.54069	595	88	4	4
19	93.38089	24.73590	589	89	4	4
20	93.43752	24.75407	531	91	4	4
21	93.56718	24.73784	525	92	4	4
22	93.52230	24.74418	521	93	4	4
23	93.34557	24.61962	515	94	4	4
24	93.59465	24.66639	484	95	4	4
25	93.45971	24.82897	484	96	4	4
26	93.68879	24.72985	462	97	4	4
27	93.68318	24.65376	443	98	4	4
28	93.27527	24.63592	436	99	4	4
29	93.63365	24.79110	371	100	4	4
30	93.57537	24.69548	337	101	4	4
31	93.60387	24.62047	315	102	4	4
32	93.36782	24.67606	308	103	4	4
33	93.66845	24.65061	305	104	4	4
34	93.52273	24.68101	287	105	4	4
35	93.40681	24.78486	265	106	4	4
36	93.35073	24.70632	250	107	4	4

From Table 5.1., it is seen that cluster analysis changes the jurisdiction of administrative blocks over the villages. This can be seen from column 6 and column 7 in Table 5.1. Tamei, block-1 having 26 villages under its administrative jurisdiction, has 30 villages after cluster analysis under its influence area. Three villages 30, 38, 43 which were earlier under block-2 and another three village 58, 59 and 72 which were earlier under block-3 is now clubbed under block-1 due to their proximity to block-1. Tousem, block-2 having 21 villages under administrative jurisdiction has only 9 villages under its influence area after cluster analysis as 12 villages are scattered far from this district-block. Tamenglong block has 32 villages after cluster analysis and Nungba, 36 villages in place of 30 each under the administrative jurisdiction. Clustering brings those villages together to a block, only when the distances between the villages and this block are shortest.

The models are again run with an administrative data set of the pilot district, Tamenglong. The resulting road networks represented using ArcView software are shown in Fig. 5.4. - 5.6. Table 5.5. - 5.7. show the outputs from all the three models. The road length developed is highest in case of Model-1 road network and the shortest in case of Model-2 road network. The difference in road length developed is quite significant in case of Model-1 and Model-2 road networks. The difference is less significant in the case of Model-2 and Model-3 road networks. In Model-2 road network, the generated road length is found to be the shortest. The optimum values obtained through the sensibility analysis are highlighted with bold letters.

Model-1 road network has a total road network of length 704.40 km of which 290.19 km is in Tamei block, 39.02 km in Tousem, 153.71 km in Tamenglong block and 221.48 km in Nungba block under Tamenglong district when cluster analysis data is used (Table 5.2.). The total road length when administrative data is used is 539.02 km with road length in the district blocks of 149.42 km, 125.76 km, 133.26 km and 130.58 km (Table 5.5.) respectively. The difference in road length developed from this model using the two data sets is quite significant. The interconnectivity among villages is very poor as depicted in Fig. 5.1. and 5.4.

Model-2 road network has a relatively shorter road length. The road lengths obtained in the four blocks using cluster data are 49.09, 18.12, 52.18 and 66.48 km (Table 5.3.) The corresponding lengths of the roads developed by this model using the administrative data are 41.86, 39.26, 47.17 and 60.68 km (Table 5.6.). The total road lengths developed in cluster data and administrative data are 185.87 and 188.97 km respectively. The road length developed in case of cluster data is found to be a little shorter than that developed using the administrative data. Interconnectivity among villages is improved as seen in Fig. 5.2. and Fig. 5.5. The populations served per km length of whole road network developed in the pilot district are 400 and 394 respectively.

The total road lengths obtained from Model-3 using cluster and administrative data are 235.41 and 275.22 km respectively (Table 5.4. - 5.7.). In this model also the cluster data produces shorter road lengths. The cluster data seems to give shorter and better road network. The interconnectivity among villages is improved much in this network. The road networks developed by this model for the four districts in Tamenglong using both the two data sets are shown in Fig. 5.3. and Fig. 5.6. Population served per km length of whole road network in the district works out to be 316 and 270 in cluster data and administrative data respectively.

The optimum figures obtained from all the three models are given in Table 5.8. and Table 5.9. Table 5.8. represents the optimum output obtained when cluster analysis data is used. Table 5.9. represents the optimum output obtained from the administrative block and village data of Tamenglong district. Summary of Table 5.8. and Table 5.9. is given in Table 5.10. Table 5.10. reveals that cluster analysis data yields more road length only in Model-1 road network. The total road lengths obtained with the same data through Model-2 and Model-3 road networks are relatively shorter. It is obvious that the road network developed through Model-1 is impractical as it involves development and maintenance of large road length. It is also found that when cluster analysis is used Model-2 and Model-3 generate shorter road lengths. The road lengths developed by Model-2 and Model-3 are comparable and both networks can be adopted.

Table 5.2. Model-1 Road Network, Cluster Analysis data, Tamenglong district

Name of District Block	*Tamei*	*Tousem*	*Tamenglong*	*Nungba*
Population	*19,143*	*4,484*	*28,402*	*22,416*
No. of village	*30*	*9*	*32*	*36*
Total Road Length (km)	290.19	39.02	153.71	221.48
Population served per km length of road network	65	114	185	101

Table 5.3. Model-2 Road Network, Cluster Analysis data, Tamenglong district

District Block-1, Tamei	***Population =19,143***		***No. of villages = 30***	
Particulars	*Mf=1.25*	*Mf=1.50*	*Mf=1.75*	*Mf-2.00*
Total Road Length (km)	49.85	50.09	**49.09**	49.09
Population served per km length of road network	384	382	**390**	390
District Block-2, Tousem	***Population = 4484***		***No. of villages = 9***	
Particulars	*Mf=1.25*	*Mf=1.50*	*Mf=1.75*	*Mf-2.00*
Total Road Length (km)	19.09	19.09	19.09	**18.12**
Population served per km length of road network	235	235	235	**247**
District Block-3, Tamenglong	***Population =28,402***		***No. of villages = 32***	
Particulars	*Mf=1.25*	*Mf=1.50*	*Mf=1.75*	*Mf-2.00*
Total Road Length (km)	**52.18**	57.27	54.65	54.66
Population served per km length of road network	**544**	496	520	520
District Block-4, Nungba	***Population = 22,416***		***No. of villages = 36***	
Particulars	*Mf=1.25*	*Mf=1.50*	*Mf=1.75*	*Mf-2.00*
Total Road Length (km)	70.10	70.10	70.10	**66.48**
Population served per km length of road network	320	320	320	**337**

Table 5.4. Model-3 Road Network, Cluster Analysis data, Tamenglong district

District Block-1, Tamei	***Population =19,143***		***No. of villages = 30***	
Particulars	*Mf=1.25*	*Mf=1.50*	*Mf=1.75*	*Mf-2.00*
Total Road Length (km)	***65.80***	70.58	66.80	66.80
Population served per km length of road network	**290**	271	286	286
District Block-2, Tousem	***Population = 4484***		***No. of villages = 9***	
Particulars	*Mf=1.25*	*Mf=1.50*	*Mf=1.75*	*Mf-2.00*
Total Road Length (km)	*22.78*	22.78	**21.72**	21.72
Population served per km length of road network	*196*	196	**206**	206
District Block-3, Tamenglong	***Population =28,402***		***No. of villages = 32***	
Particulars	*Mf=1.25*	*Mf=1.50*	*Mf=1.75*	*Mf-2.00*
Total Road Length (km)	**66.83**	70.00	68.66	68.31
Population served per km length of road network	**424**	405	413	415
District Block-4, Nungba	***Population = 22,416***		***No. of villages = 36***	
Particulars	*Mf=1.25*	*Mf=1.50*	*Mf=1.75*	*Mf-2.00*
Total Road Length (km)	**81.06**	90.51	89.99	90.57
Population served per km length of road network	**276**	247	249	247

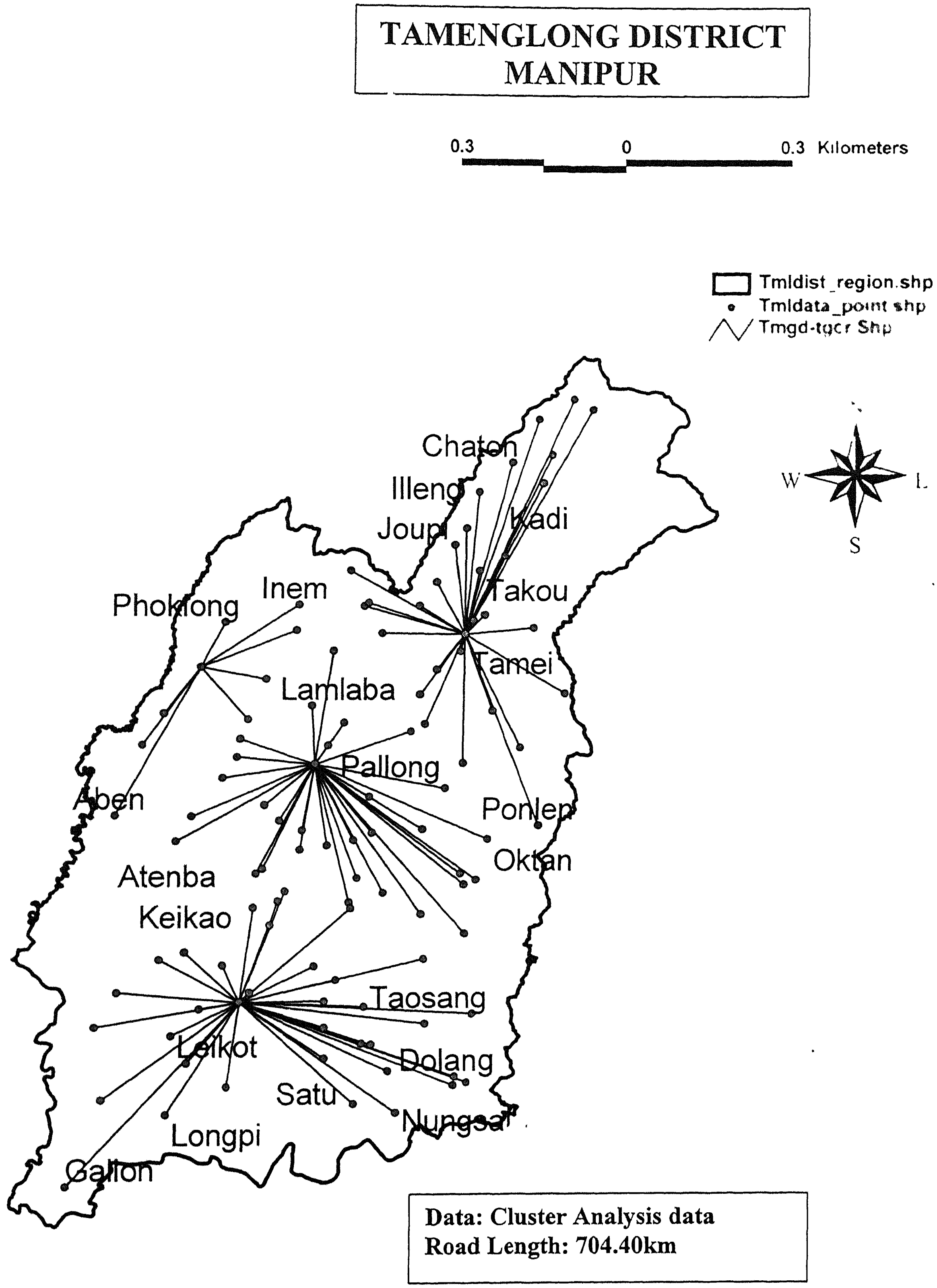


Fig. 5.1. Model-1 Road Network

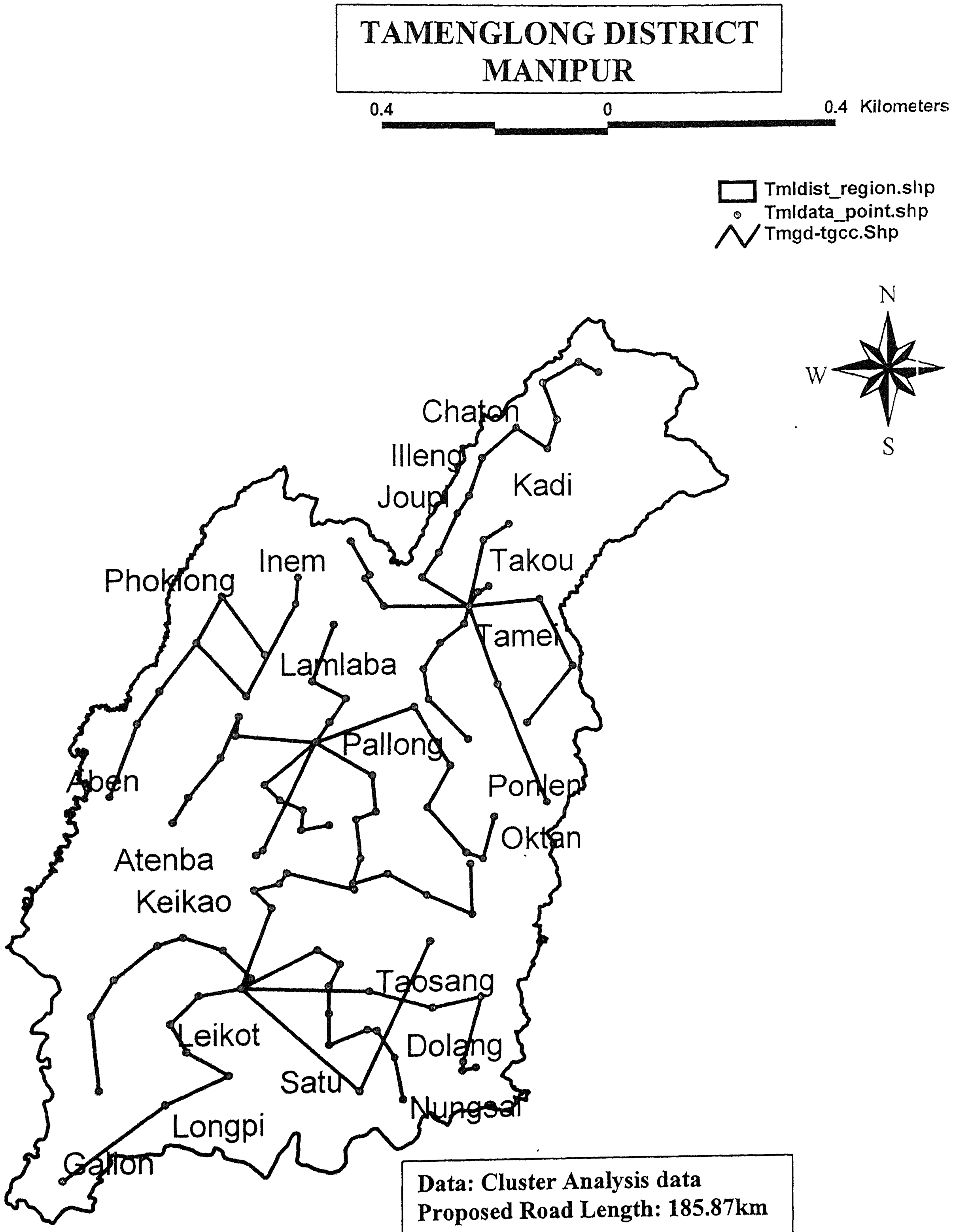


Fig. 5.2. Proposed Model-2 Road Network

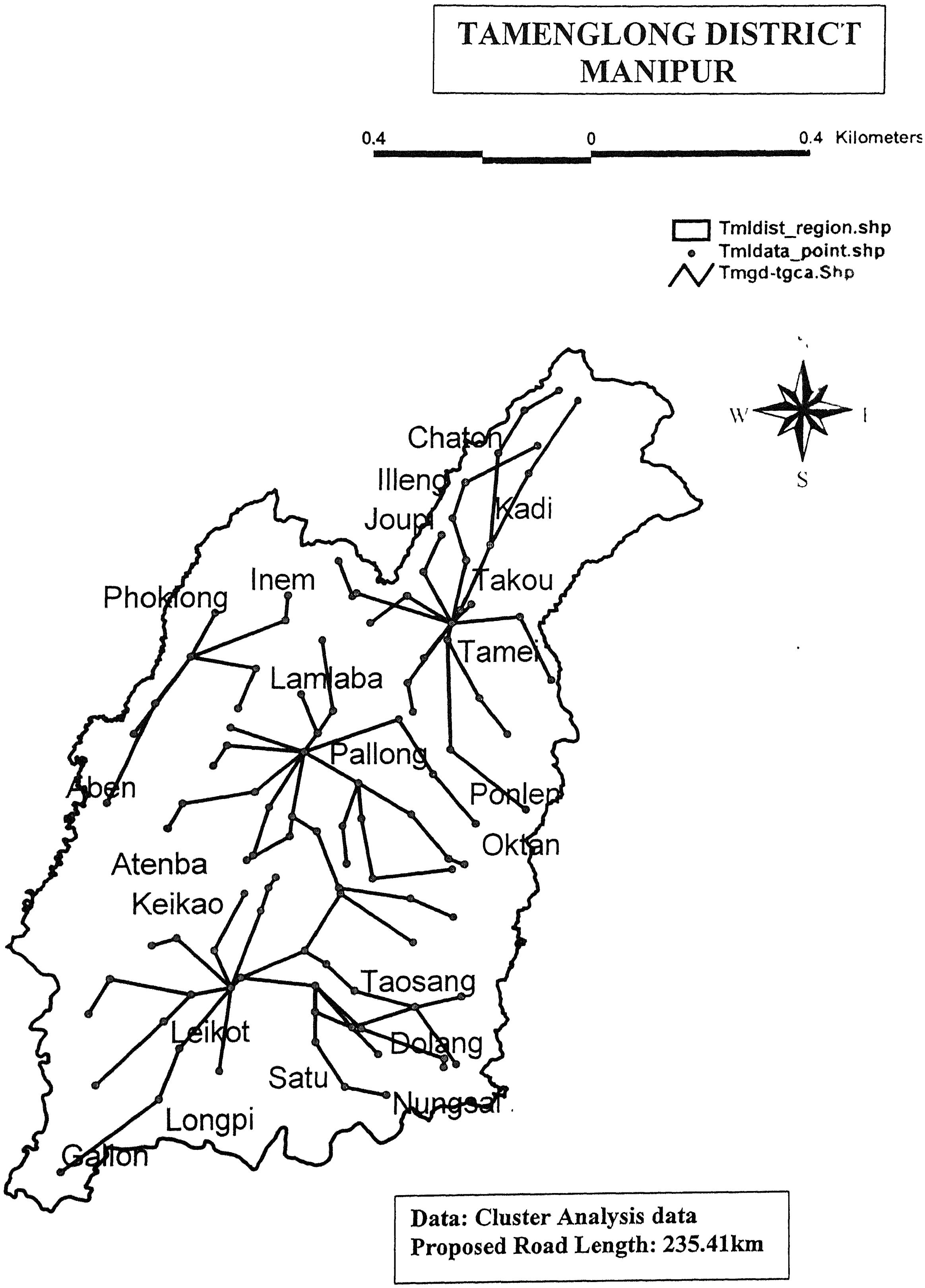


Fig. 5.3. Proposed Model-3 Road Network

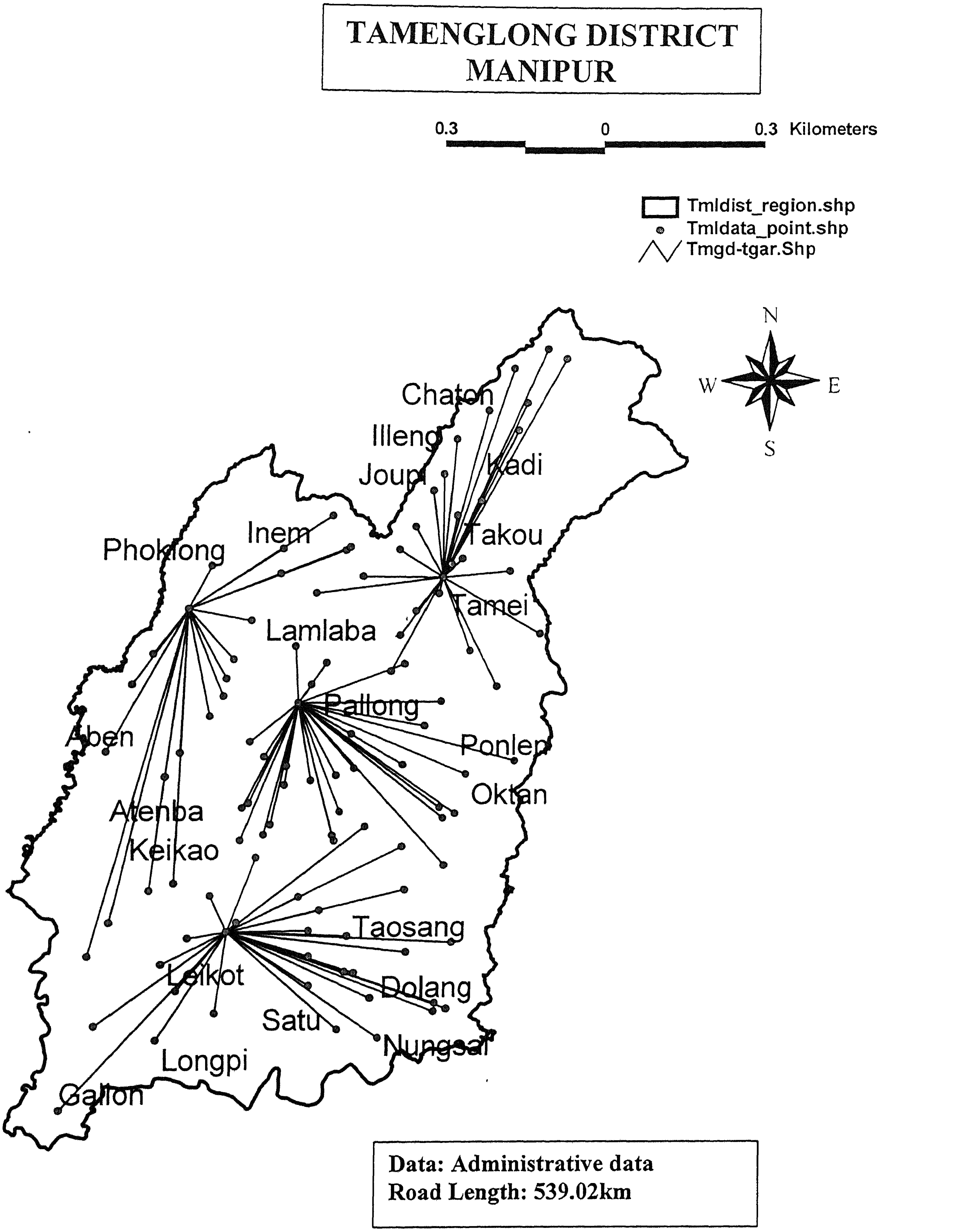


Fig. 5.4. Model-1 Road Network

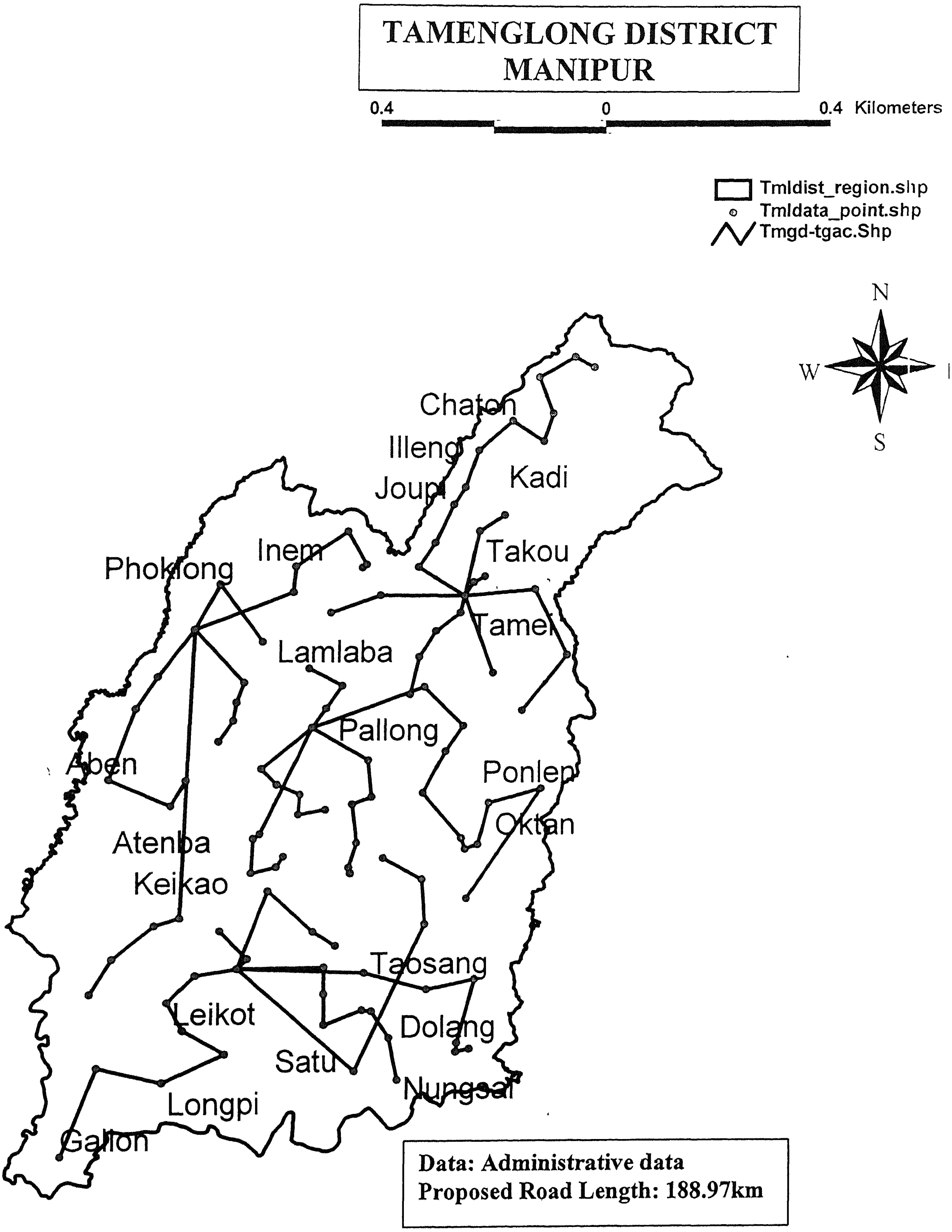
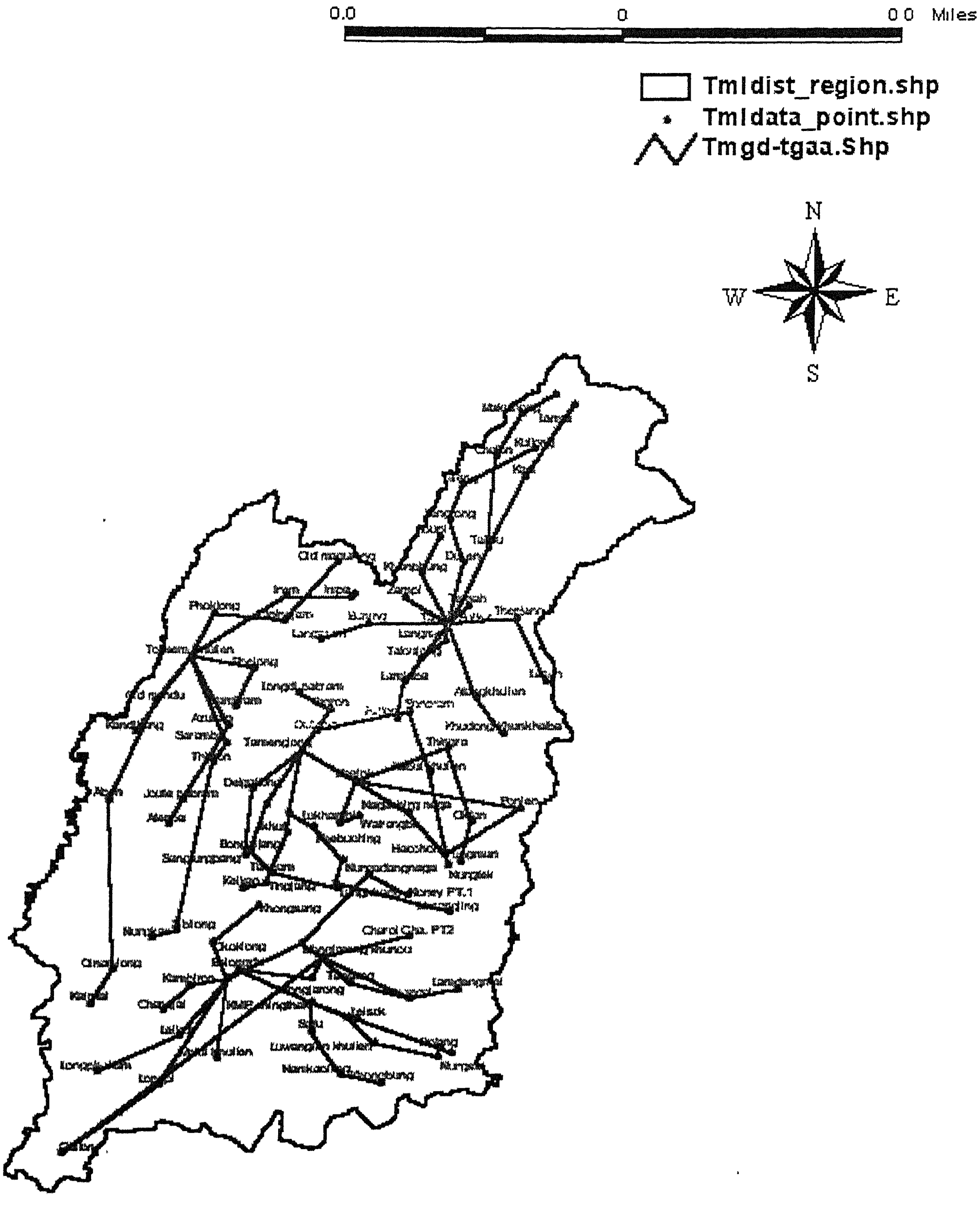


Fig. 5.5. Proposed Model-2 Road Network

TAMENGLONG DISTRICT MANIPUR



Data: Administrative data
Proposed Road Length: 275.22km

Fig. 5.6. Proposed Model-3 Road Network

Table 5.5. Model-1 Road Network, Administrative data, Tamenglong district

Name of District Block	*Tamei*	*Tousem*	*Tamenglong*	*Nungba*
Population	*16,995*	*11,126*	*25,062*	*21,262*
No. of village	*26*	*21*	*30*	*30*
Total Road Length (km)	149.42	125.76	133.26	130.58
Population served per km length of road network	113	88	188	162

Table 5.6. Model-2 Road Network, Administrative data, Tamenglong district

District Block-1, Tamei	***Population =16,995***		***No. of villages = 26***	
Particulars	*Mf=1.25*	*Mf=1.50*	*Mf=1.75*	*Mf-2.00*
Total Road Length (km)	**41.86**	48.54	42.06	44.72
Population served per km length of road network	**406**	350	404	380
District Block-2, Tousem	***Population = 11,126***		***No. of villages = 21***	
Particulars	*Mf=1.25*	*Mf=1.50*	*Mf=1.75*	*Mf-2.00*
Total Road Length (km)	**39.26**	39.26	46.58	46.67
Population served per km length of road network	**283**	283	239	238
District Block-3, Tamenglong	***Population =25,062***		***No. of villages = 30***	
Particulars	*Mf=1.25*	*Mf=1.50*	*Mf=1.75*	*Mf-2.00*
Total Road Length (km)	48.63	48.19	**47.17**	50.14
Population served per km length of road network	515	520	**531**	500
District Block-4, Nungba	***Population = 21,262***		***No. of villages = 30***	
Particulars	*Mf=1.25*	*Mf=1.50*	*Mf=1.75*	*Mf-2.00*
Total Road Length (km)	60.71	62.17	**60.68**	79.22
Population served per km length of road network	350	342	**350**	268

Table 5.7. Model-3 Road Network, Administrative data, Tamenglong district

District Block-1, Tamei	***Population =16,995***		***No. of villages = 26***	
Particulars	*Mf=1.25*	*Mf=1.50*	*Mf=1.75*	*Mf-2.00*
Total Road Length (km)	**55.59**	55.59	59.27	59.27
Population served per km length of road network	**305**	305	286	286
District Block-2, Tousem	***Population = 11,126***		***No. of villages = 21***	
Particulars	*Mf=1.25*	*Mf=1.50*	*Mf=1.75*	*Mf-2.00*
Total Road Length (km)	66.20	66.20	62.46	**59.14**
Population served per km length of road network	168	168	178	**188**
District Block-3, Tamenglong	***Population =25,062***		***No. of villages = 30***	
Particulars	*Mf=1.25*	*Mf=1.50*	*Mf=1.75*	*Mf-2.00*
Total Road Length (km)	73.14	**72.61**	80.76	81.60
Population served per km length of road network	342	**345**	310	307
District Block-4, Nungba	***Population = 21,262***		***No. of villages = 30***	
Particulars	*Mf=1.25*	*Mf=1.50*	*Mf=1.75*	*Mf-2.00*
Total Road Length (km)	**87.88**	92.84	102.53	101.71
Population served per km length of road network	**241**	229	207	209

Table. 5.8. ***Comparison of Road lengths developed from the three models, Tamenglong district (Cluster analysis data)***

1. a) Optimum value obtained using cluster analysis data, Tamenglong district									
Particulars	Population	Model Adopted							
		Method1		Method2			Method3		
		Rd length	pskm	*mf*	Rd length	pskm	*mf*	Rd length	pskm
1.Tamei Block No. of Village = 30	*19143*	290.19	65	1.75	**49.09**	**390**	1.25	65.80	290
2.Tousem Block No. of Village = 9	**4484**	39.02	114	2	**18.12**	**247**	1.75	21.72	206
3.Tamenglong No. of Village = 32	**28402**	153.71	184	1.25	**52.18**	**544**	1.25	66.83	424
Nungba Block No. of Village = 36	*22416*	221.48	101	2	**66.48**	**337**	1.25	81.06	276
GRAND TOTAL	**74445**	**704.40**	**106**		***185.87***	***400***		**235.41**	**316**

Table. 5.9. ***Comparison of Road lengths developed from the three models, Tamenglong district (Administrative data)***

1. b) Optimum value obtained using Administrative Block data, Tamenglong district									
Particulars	Population	Model Adopted							
		Method1		Method2			Method3		
		Rd length	pskm	*Mf*	Rd length	Pskm	*mf*	Rd length	pskm
1.Tamei Block No. of Village = 26	*16995*	149.42	113	1.25	**41.86**	**406**	1.25	55.59	305
2.Tousem Block No. of Village = 21	*11126*	125.76	88	1.25	**39.26**	**283**	2.00	59.14	188
3.Tamenglong No. of Village = 30	*25062*	133.26	188	1.75	**47.17**	**531**	1.50	72.61	345
4. Nungba Block No. of Village = 30	*21262*	130.58	162	1.75	**60.68**	**350**	1.25	87.88	241
GRND TTOTAL	74445	539.02	138		***188.97***	***394***		275.22	270

Table 5.10. Optimum Road lengths from Cluster analysis data and Administrative data, Tamenglong district

Particulars	Model-1		Model-2		Model-3	
	Cluster	Administ	Cluster	Administ	Cluster	Administ
Tamei Block						
Population served	19143	16995	19143	16995	19143	1699
Road length developed	290.19	149.42	49.09	41.86	65.80	55.5
Pop served/km of road	65	113	390	406	290	30
Tousem Block						
Population served	4484	11126	4484	11126	4484	1112
Road length developed	39.02	125.76	18.12	39.26	21.72	59.1
Pop served/km of road	114	88	247	283	206	18
Tamenglong Block						
Population served	28402	25062	28402	25062	28402	2506
Road length developed	153.71	133.26	52.18	47.17	66.83	72.6
Pop served/km of road	185	188	544	531	424	34
Nungba Block						
Population served	22416	21262	22416	21262	22416	2126
Road length developed	221.48	130.58	66.48	60.68	81.06	87.8
Pop served/km of road	101	162	337	350	276	24
Total population served	**74445**	**74445**	**74445**	**74445**	**74445**	**7444**
Grand Total (road length)	**704.40**	**539.02**	**185.87**	**188.97**	**235.41**	**275.2**
Total Population served/km of road length developed	**106**	**138**	**400**	**394**	**316**	**27**

Table. 5.11. Comparison of Road lengths developed from the three models, Bishnupur district (Cluster analysis data)

2. a) Optimum value obtained using Cluster analysis data (Bishnupur District)										
Particulars	Population	Model Adopted								
		Model - 1		Model – 2			Method3			
		Rd length	pskm	*Mf*	Rd length	Pskm	*mf*	Rd length	pskm	
1. Bishnupur Block Population =79,598 No of Village = 23	*79598*	74.52	1,068	1.25	**13.26**	**6,005**	1.25	28.11	2831	
2. Moirang Block Population =94,879 No. of Village = 22	*94879*	109.49	866	1.25	**17.60**	**5,390**	1.25	28.11	3375	
GRAND TOTAL	174477	**184.01**	**948**		***30.86***	***5654***		**56.22**	**3104**	

Table. 5.12. Comparison of Road lengths developed from the three models, Bishnupur district (Administrative data)

2. b) Optimum value obtained using administrative block data (Bishnupur District)									
Particulars	Population	Model Adopted							
		Model - 1		Model - 2			Model - 3		
		Rd length	*pskm*	*mf*	*Rd length*	*pskm*	*mf*	*Rd length*	*pskm*
1. Bishnupur Block Population =87,653 No. of Village = 27	*87653*	74.04	1,183	1.25	**16.08**	**5,453**	1.5	36.50	2,401
2.Moirang Block Population =86,824 No. of Village = 18	*86824*	81.27	1068	1.75	**15.98**	**5,432**	1.5	23.56	3,685
GRAND TOTAL	174477	**155.31**	**1123**		***32.06***	***5442***		**60.06**	**2905**

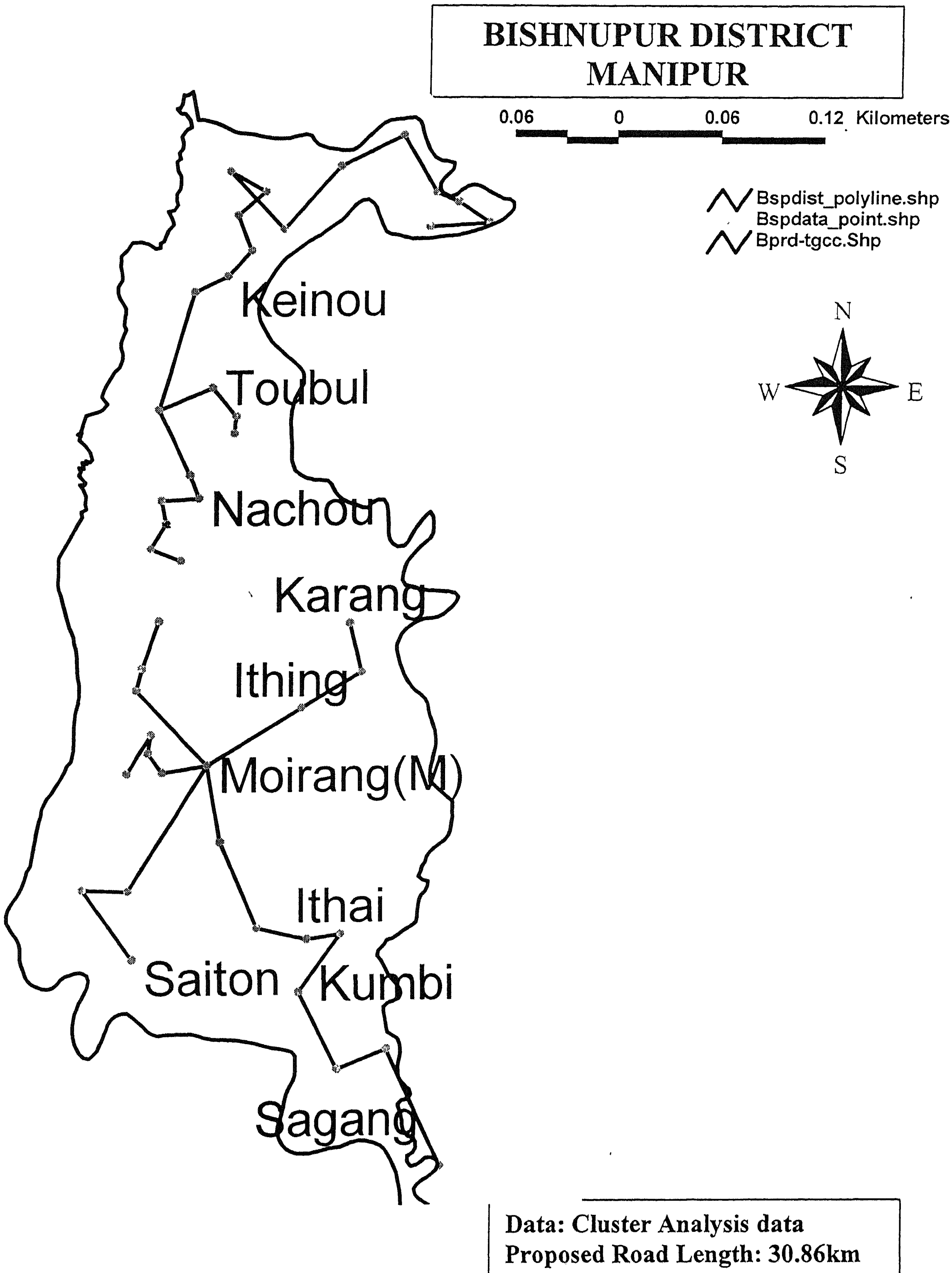


Fig. 5.7. Proposed Model-2 Road Network

Fig. 5.8. Proposed Model-2 Road Network

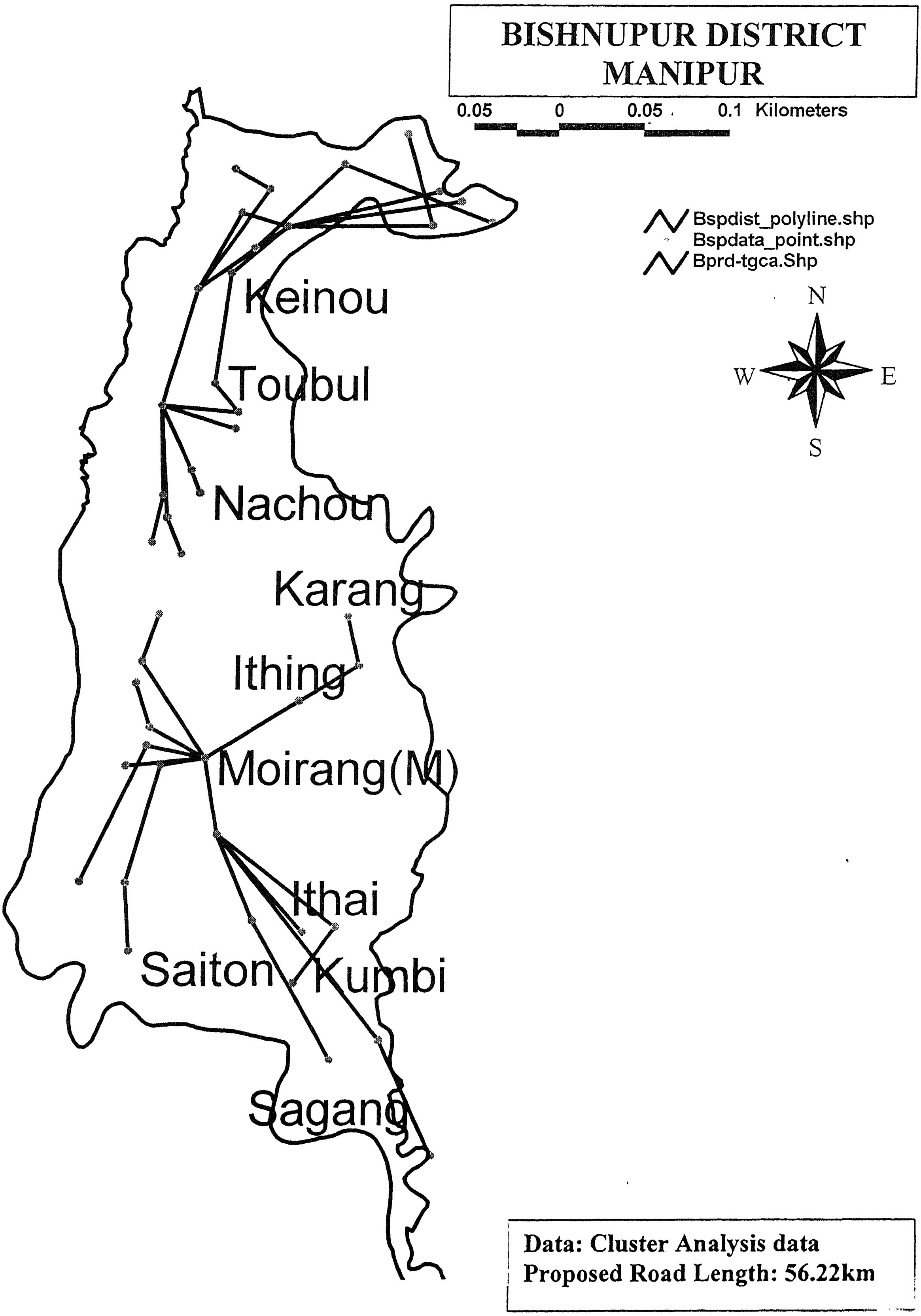
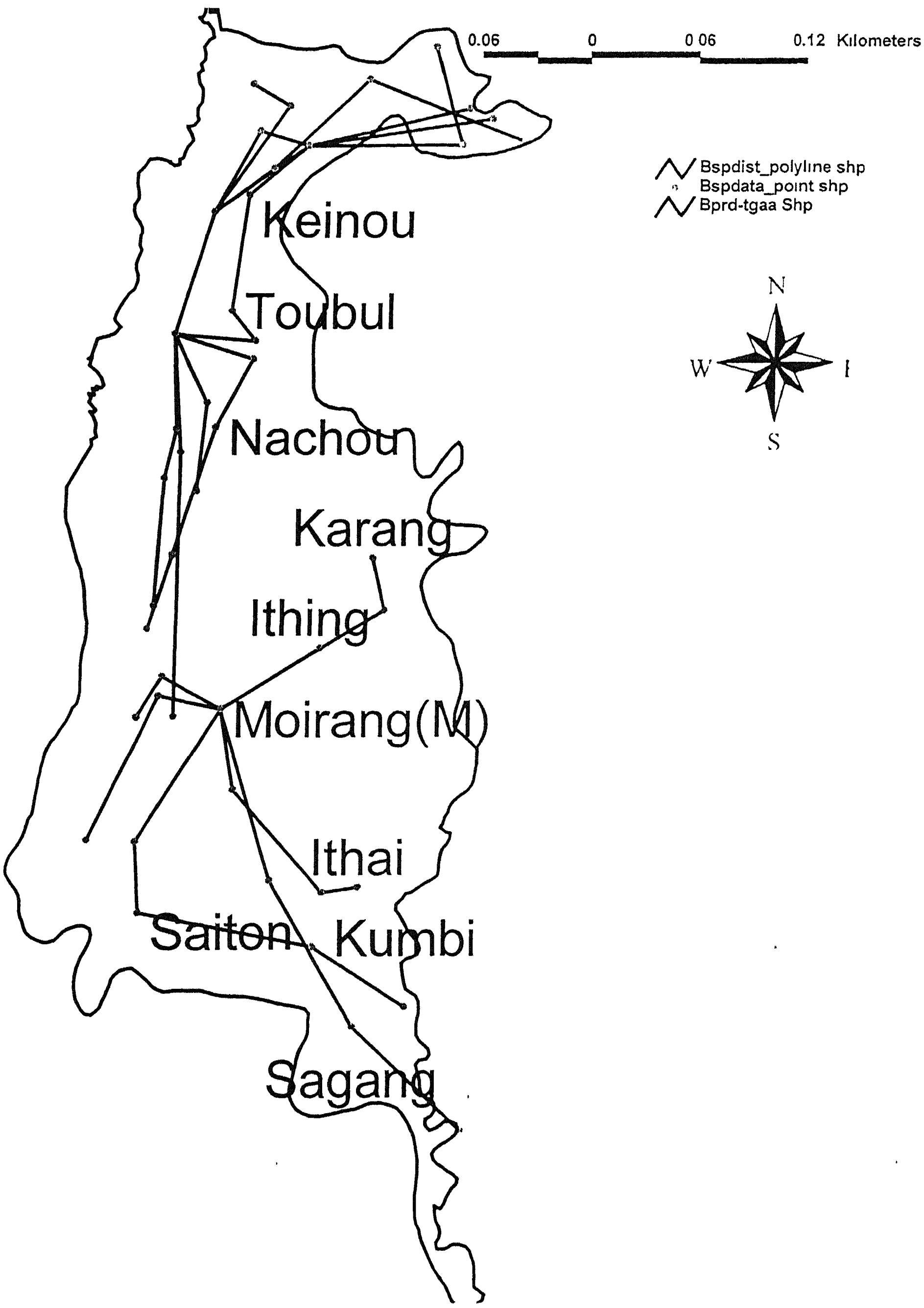


Fig. 5.9. Proposed Model-3 Road Network

BISHNUPUR DISTRICT MANIPUR



Data: Administrative data
Proposed Road Length: 60.06km

Fig. 5.10. Proposed Model-3 Road Network

Tables 5.11. - 5.12. gives the road lengths obtained from the three developed heuristic models in the district of Bishnupur when cluster data and administrative data sets are used. Model-1 road network lengths are 184.01 and 155.31 km. Road lengths obtained from Model-2 road network are 30.86 and 32.06 km while that from Model-3 are 56.22 and 60.06 km when cluster and administrative data sets are used. The road length in Model-2 road network is the shortest. This also shows that when the villages are closely situated the difference in road lengths resulted from the two data sets are quite insignificant. The roads networks developed using the optimum values are shown in Fig. 5.7. - 5.10. The advantage of clustering technique over the administrative one is clear as seen in these four figs. The overlapping of influence area of a block over the other is avoided in the clustering method of delineation of area for a block that ultimately reduces the road length in case of cluster data.

Fig. 5.11.-5.14. shows the road networks developed for Churachandpur district by Model-2 and Model-3 using the cluster and administrative data. The total road lengths for these two data sets in case of Model-1 road networks are 1,156.61 and 1,011.37 km. In Model-2 road networks, these road lengths are 263.13 km and 266.80 km with population served per unit length of 515 and 507 respectively. The road lengths developed in Model-3 road networks when these two data sets are used are 364.90 and 374.65 km with respective population served per unit length of 371 and 361. The cluster data gives shorter road lengths in both Model-2 and Model-3.

In both Bishnupur and Churachandpur districts the road lengths in Model-2 road networks gives the shortest road length. These results conform to the one that obtained from the data in the pilot district, Tamenglong.

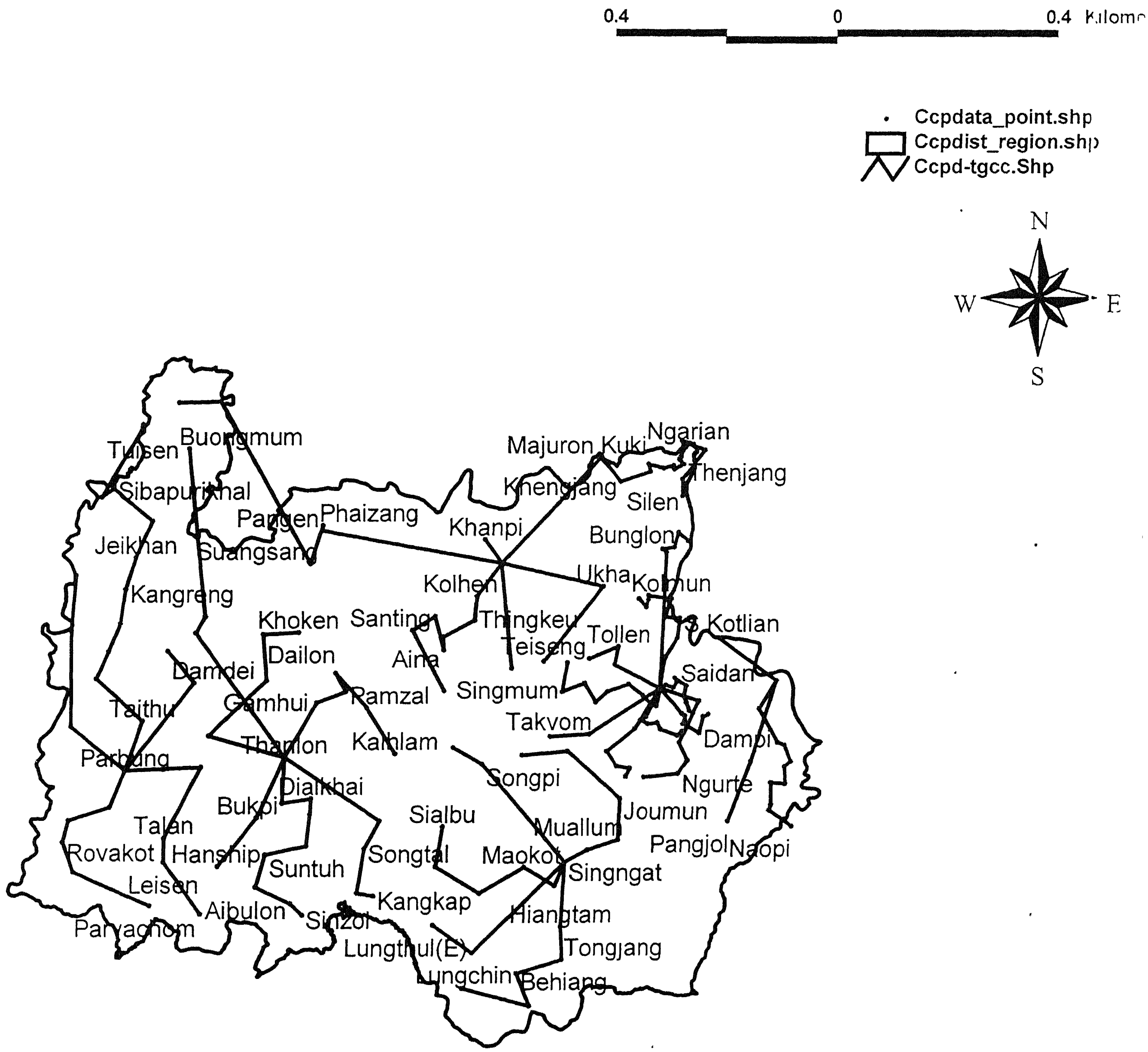
Table. 5.13. Comparison of Road lengths developed from the three models, Churachandpur district (Cluster analysis data)

3. a) Optimum value obtained using cluster analysis data (Churachandpur District)										
Particulars	Population	Model Adopted								
		Model - 1		Model – 2			Model - 3			
		Rd length	pskm	*mf*	Rd length	Pskm	*mf*	Rd length	Pskm	
1. Parbung Block No. of Village = 31	*19643*	253.86	77	1.25	**49.71**	**395**	1.25	69.06	284	
2. Thanlon Block No. of Village = 28	*15974*	178.06	89	1.25	**54.14**	**295**	1.25	72.88	219	
3. Henglep Block No. of Village = 25	*13264*	218.52	60	1.25	**54.18**	**245**	2	88.18	150	
4. Churachandpur No. of Village = 64	*66283*	316.48	209	1.25	**49.47**	**1340**	1.25	62.53	1060	
5. Samulamlan No. of Village = 15	*7452*	73.65	101	1.25	**16.15**	**461**	1.25	26.73	278	
6. Singhat Block No. of Village = 19	*12807*	116.04	110	1.25	**39.48**	**324**	2	45.52	281	
GRAND TOTAL	**135423**	**1156.61**	**117**		**263.13**	**515**		**364.90**	**371**	

Table. 5.14. Comparison of Road lengths developed from the three models, Churachandpur district (Administrative data)

3. b) Optimum value obtained using Administrative Block data (Churachandpur District)									
Particulars	Population	Model Adopted							
		Model - 1		Model – 2			Model – 3		
		Rd length	Pskm	*mf*	Rd length	Pskm	*mf*	Rd length	pskm
1.Parbung Block No. of Village = 31	*22042*	313.04	70	1.25	**53.77**	**410**	1.25	87.07	253
2.Thanlon Block No. of Village =28	*16378*	179.70	91	1.25	**47.96**	**341**	1.25	75.12	218
3. Henglep Block No. of Village = 25	*10008*	128.59	77	1.25	**37.91**	**264**	1.25	56.51	177
4. Churachandpur No. of Village = 64	*68296*	209.69	325	1.25	**62.08**	**1100**	1.25	71.77	951
5. Samulamlan No. of Village = 15	*6425*	75.39	85	1.5	**23.12**	**278**	1.25	37.57	171
6. Singhat Block No. of Village = 19	*12274*	104.96	116	2	**41.96**	**349**	1.5	46.61	263
GRAND TOTAL	**135423**	**1011.37**	**134**		**266.80**	**507**		**374.65**	**361**

CHURACHANDPUR DISTRICT
MANIPUR



Data: Cluster Analysis data
Proposed Road Length: 263.13km

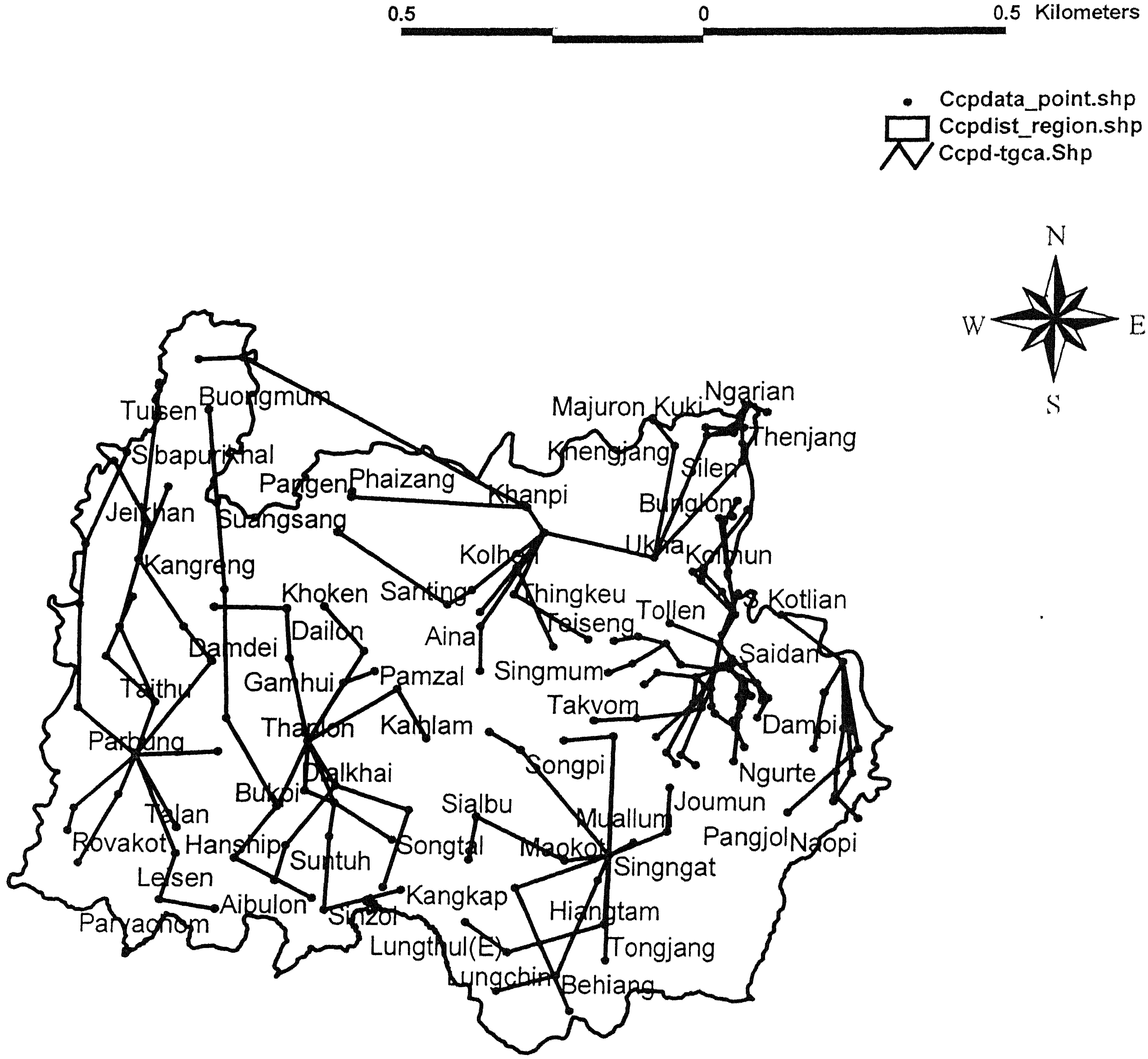
Fig. 5.11. Proposed Model-2 Road Network

CHURACHANDPUR DISTRICT MANIPUR

Data: Administrative data
Proposed Road Length: 266.80km

Fig. 5.12. Proposed Model-2 Road Network

CHURACHANDPUR DISTRICT MANIPUR



Data: Cluster Analysis data
Proposed Road Length: 364.90km

Fig. 5.13. Proposed Model-3 Road Network

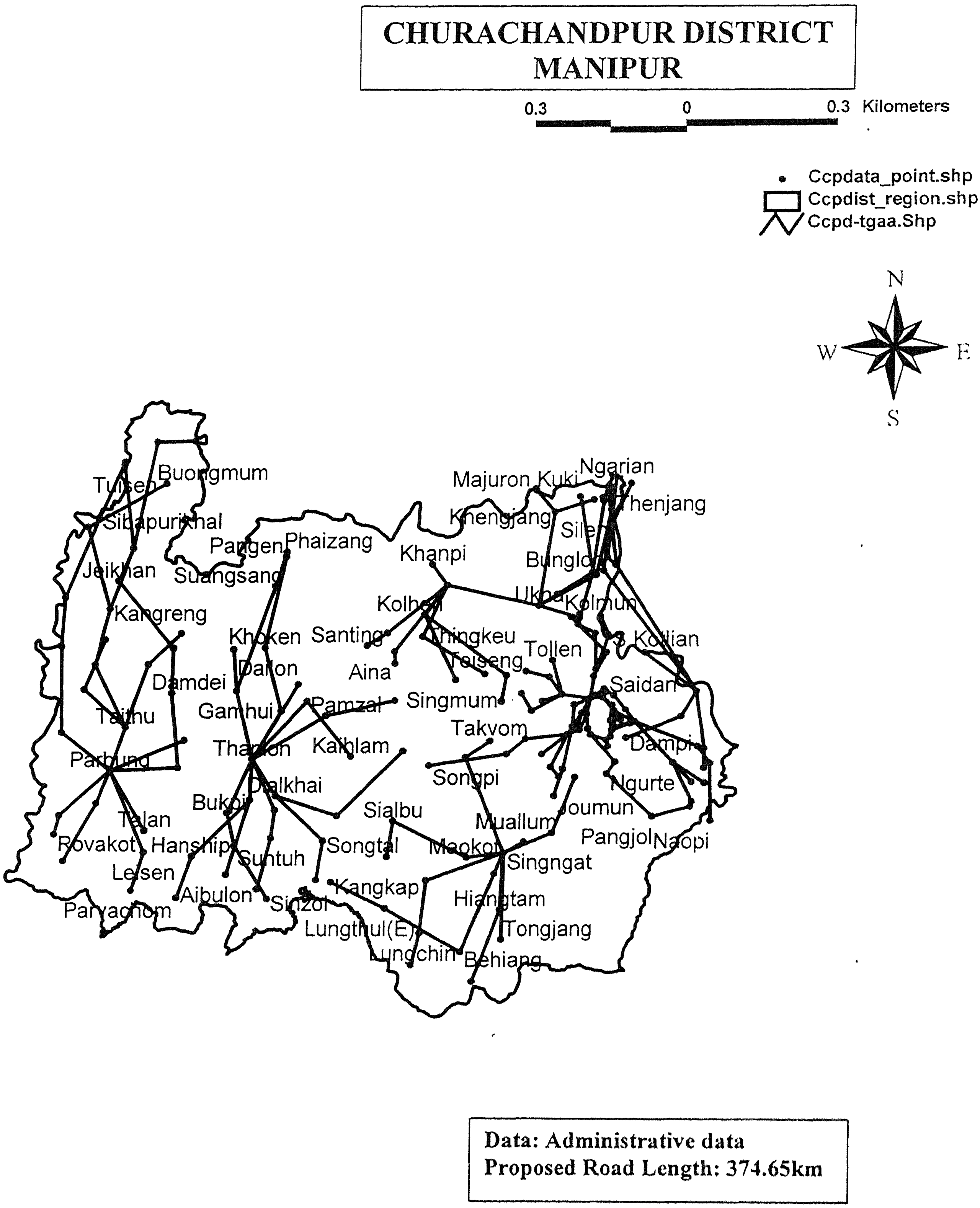


Fig. 5.14. Proposed Model-3 Road Network

Table 5.15. Comparison of total road lengths developed from the 3 models in 3 districts of Manipur

Particular	Model-1			Model-2			Model-3		
	TMG	BPR	CCPR	TMG	BPR	CCPR	TMG	BPR	CCPR
Cluster analysis data									
Road length	704.40	184.01	1156.61	185.87	30.86	263.13	235.41	56.22	364.90
Population Served	74445	174477	135423	74445	174477	135423	74445	174477	135423
Population served per km	106	948	117	400	5654	515	316	3104	371
Administrative block data									
Particular	**Model-1**			**Model-2**			**Model-3**		
	TMG	**BPR**	**CCPR**	**TMG**	**BPR**	**CCPR**	**TMG**	**BPR**	**CCPR**
Road length	539.02	155.31	1011.37	188.97	32.06	266.80	275.22	60.06	374.65
Population Served	74445	174477	135423	74445	174477	135423	74445	174477	135423
Population served per km	138	1123	134	394	5442	507	270	2905	361

The total road length developed for the three districts of Manipur viz. i)Tamenglong, ii) Bishnupur and iii) Churachandpur obtained from the two data sets, a) cluster analysis data and b) administrative data are shown in Table 5.15. As the number of data sets are low it can not be definitely concluded which method of delineation of block boundary is better. However, from the available data sets and outputs obtained from these data sets through Model-2 and Model-3, it can be inferred that cluster analysis technique results in shorter road length and is a better technique.

5.3. Summary

In Model-1, length of road network is too long and is not advisable for implementation. It is seen from the pilot district that Model-2 road network is more economic in terms of road length and population served per unit length of road. The same trend is found in the other two districts, Bishnupur and Churachandpur. The superiority of delineation of boundary by using cluster analysis technique over existing administrative one can not be fully confirmed due to the low number of data sets available and tested, although cluster analysis technique produces better results in Model-2 and Model-3. This could be confirmed by analyzing more data sets. In spite of the little additional road length, Model-3 road network has the advantage of providing better connectivity with more number of villages and the district block. Model-3 also takes into account of the other village characteristics like population, which means that a change in the population of any of the villages will have effect on the routes in case of Model-3 road networks. It seems to be more realistic and practicable. Since the inhabitants are very thinly populated and there are no much economic activities, like agricultural or industrial activities on these remote inhabitants, the adoption of the Model-2 road network or Model-3 road network shall depend on the cost or financial component involved.

6. CONCLUSION

6.1. Summary

Scientific planning of rural roads is important to get an economical, feasible and lasting road network to serve a community. Rural road planning can be done in a scientific and rational approach by developing scientific tools and techniques thus making the complex and time-consuming process of rural road planning easier and simpler. In India provision for planning and construction of rural roads were given only during the Third Five-Year Plan. The Pradhan Mantri Gram Sadak Yojana (PMGSY) launched in the year 2000 is another Centrally sponsored scheme by the Central Government for the development of rural roads in modern India. Providing road connectivity, through good all-weather roads to all rural habitations with a population more than i) 250 in hilly/desert areas, and ii) 500 in plain areas, by the year 2007 is the objective of the PMGSY. There is hardly any record for rural road planning in a scientific manner in India. In the present study, models for optimum rural road planning are developed so that the PMGSY can be effectively implemented.

Model-1, "Direct Connectivity of District Block and Villages" generates a road network by connecting the district block with each and every villages under its influence area. The road length developed from this model is longest. In Model-2, "Road Length Threshold Criteria" road network is based on the distance between the district block and the village to be connected. Road network in this model always starts from the district block and extends towards the unconnected villages away from the district block. In Model-3, "Threshold Road Length and Population Criteria" road networks is generated from the farthest unconnected villages and extend toward the district block. The optimum rural road network is represented graphically using GIS techniques by interfacing the model outputs with a GIS software, ArcInfo/ArcView. The formulated models for rural road planning are successfully applied to the three districts of Manipur: Tamenglong, Bishnupur and Churachandpur.

6.2. Conclusion

Rural road planning is done in a district level considering a district as a unit of planning. Planning is conveniently done in the middle level of administrative unit, i.e., Block or Mandal as data collection and obtaining approval of local bodies is an important factor in formulating a master plan for rural roads. The district level planning also enables implementation, monitoring and coordination of the project more effectively and efficiently. Thus road network is developed in the block and district levels. The road network in a State/Union Territory is the result of these block and district level road networks. Effective administration, maintenance of law and order, distribution of essential commodities and basic services fails considerably a) when jurisdiction of established administrative block is not properly done and b) when a few villages are located very far from the district block. Clustering of remote villages to suitable district blocks is done to obtain an economic and better planning and effective discharge of basic services. Clustering of villages with a suitable technique is important to get the optimum road network. In the present work clustering is done based on the Euclidean distance between a district block and a village.

The developed network models enable to plan a network of rural roads with maximum social benefits. The proposed network obtained from the models maximizes population served per km length. Model-1 generates a road network with large road lengths and is not advisable for implementation as it involves large road lengths for construction and maintenance. Model-2 generates the shortest road length. Both Model-2 and Model3 road networks are recommended for implementation. The advantage of Model-2 road network is that it is the shortest and the construction and maintenance cost will be least among the three road networks generated. Model-3 road network has the merit of providing more interconnectivity among the villages and takes into account of the village characteristics in addition to distance which means that changes in the demography changes shape of the road network.

The road network models are based on the spatial locations of the villages and district block and their demographic features. The developed models are integrated with GIS to have a good representation of the road network system. Both spatial and non-spatial inputs and outputs of the models are used for to present the system visually on the ArcView platform. The visual representation of the system enables to feel and perceive the system and helps in decision making process and changes while planning.

6.3. Limitations and Scope for further work

The limitation of the present work is that of lack of sufficient data to model and plan the rural network such as topographic information, socio-demographic data. GIS is used as the display platform of transportation modeling. The low number of data sets used for testing the models cannot definitely evaluate the merit of the delineation of area for a block by clustering technique over the existing administrative one.

The lack of contour information, and toposheets causes the design of grade and alignment of the road network impossible and necessitates the assumption of a factor to the developed road length to compensate and to give a practicable cost of the road network. The road network developed from this study gives only the euclidean distance between two points. However, by adopting a factor of 1.5 or 1.75 to the developed road length and available unit cost of road construction, one can estimate the construction cost approximately.

One important avenue left in the present work is the development of a module to interface with this model so that any typical computer user without GIS training can explore and integrate several visualization techniques. Further efforts are recommended to build the model calculation and themes display together in GIS Arc View, as such, users only need to input the source data to get the desired results. The issue of automating alignments to produce low cost, high quality routes by converging remotely sensed imaging geospatial data, softcopy photogrammetry and alignment optimization techniques are some of the areas that is left for further exploration.

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Table A-1 Particulars of Tamenglong district

1.	Geographical area	*4,391 sq Kms.*
2.	Population	*86,278* (1991 census)
3.	Altitude (above MSL)	*1260 m*
4.	Latitude (HQ)	*24.59 N*
5.	Longitude (HQ)	*93.30 E*
6.	Humidity	*76 (Min), 92 (Max)*
7.	Rainfall (HQ)	*3135 mm.*
8.	Temperature	*31°C (Max) 4°C (Min)*
9.	Literacy	*50.16 %*
10.	Sub-Divisions	*Tamenglong, Tamei, Tousem, Nungba*
11.	Main Tribes (Inhabitants)	*Zeliangrongs, Nagas, Kukis, Chirus, Hmars, Khasis*
12.	National Highways	*NH 53* (Imphal-Silchar)
14.	State Highways	*I.T. Road, Old Cachar Road, Tamenglong Khongsang Road*
15.	Major rivers	*Iyei, Irang, Barak, Makru*

Table A-2. Block-wise distribution of population

Sl	Name of TD-Block	0-199	200-499	500-1999	2000-4999	5000-9999	Total
1	Tousem	35	15	10	-	-	60
2	Tamei	2	12	16	-	-	30
3	Nungba	23	18	15	2	-	58
4	Tamenglong	13	17	15	-	1	46
	District	**73**	**62**	**56**	**2**	**1**	**194**

Table A-3. GIS database of Tamgnlong district

Sl	name	blckname	x_coord	y_coord	totpop	dist	torv	placeid	blockid
1	Tamenglong	Tamenglong	93.50797	25.0081	7733	TML	V	TML.3V.08	TML.3
2	KMP.chingthak	Nungba	93.52241	24.71481	2996	TML	V	TML.4V.27	TML.4
3	Noney PT.1	Nungba	93.63022	24.84076	2230	TML	V	TML.4V.03	TML.4
4	Kadi	Tamei	93.76296	25.32162	1444	TML	V	TML.1V.07	TML.1
5	Tamei	Tamei	93.67543	25.1526	1330	TML	V	TML.1V.15	TML.1
6	Nungnang PT1&PT2	Nungba	93.53488	24.76783	1315	TML	V	TML.4V.30	TML.4
7	Marangjing	Tamenglong	93.67905	24.81927	1268	TML	V	TML.3V.37	TML.3
8	Nungba HQ.	Nungba	93.42619	24.74321	1245	TML	V	TML.4V.37	TML.4
9	Tousem Khullen	Tousem	93.37842	25.11623	1181	TML	V	TML.2V.06	TML.2
10	Awang khul	Tamenglong	93.54878	24.85412	1147	TML	V	TML.3V.22	TML.3
11	Chaton	Tamei	93.7278	25.3445	1134	TML	V	TML.1V.05	TML.1
12	Lemta	Tamei	93.81861	25.40336	1028	TML	V	TML.1V.03	TML.1
13	Akhui	Tamenglong	93.49229	24.91279	1002	TML	V	TML.3V.12	TML.3
14	Bhalok	Tamenglong	93.57031	24.97195	996	TML	V	TML.3V.05	TML.3
15	Oinamlong	Tousem	93.29117	24.75432	958	TML	V	TML.2V.26	TML.2
16	Thangai	Nungba	93.63603	24.71885	947	TML	V	TML.4V.07	TML.4
17	Illeng	Tamei	93.69038	25.31183	901	TML	V	TML.1V.06	TML.1
18	Dolang	Nungba	93.66937	24.66021	896	TML	V	TML.4V.08	TML.4
19	Lenglong	Tamei	93.67611	25.27146	871	TML	V	TML.1V.09	TML.1
20	Mongjarong khunou	Nungba	93.5101	24.78334	866	TML	V	TML.4V.34	TML.4
21	Tharon	Tamenglong	93.54096	25.05449	864	TML	V	TML.3V.01	TML.3
22	Namkaolong	Nungba	93.55642	24.63047	853	TML	V	TML.4V.15	TML.4
23	Dailong	Tamenglong	93.52326	25.02928	838	TML	V	TML.3V.07	TML.3
24	Haochong	Tamenglong	93.67322	24.88577	828	TML	V	TML.3V.40	TML.3
25	Kuilong	Tamei	93.77299	25.35278	802	TML	V	TML.1V.04	TML.1
26	Nallong	Tamei	93.79714	25.41481	793	TML	V	TML.1V.01	TML.1
27	Shongphel khunou	Tamenglong	93.55735	24.88122	793	TML	V	TML.3V.26	TML.3
28	Takou	Tamei	93.71959	25.24086	790	TML	V	TML.1V.08	TML.1
29	Wairangba	Tamenglong	93.57389	24.9318	781	TML	V	TML.3V.04	TML.3
30	Langmei	Tamei	93.67073	25.13384	759	TML	V	TML.1V.18	TML.1
31	Thiulon	Tousem	93.4043	24.99306	732	TML	V	TML.2V.49	TML.2
32	Sonpram	Tamenglong	93.63182	25.05285	713	TML	V	TML.3V.02	TML.3
33	Makuinong	Tamei	93.75766	25.39246	681	TML	V	TML.1V.02	TML.1
34	Thenjang	Tamei	93.75362	25.15952	680	TML	V	TML.1V.16	TML.1
35	Pallong	Tamei	93.61609	25.04474	677	TML	V	TML.1V.25	TML.1
36	Old magulong	Tousem	93.54664	25.22371	676	TML	V	TML.2V.60	TML.2
37	Mokti Khullen	Nungba	93.41309	24.65001	671	TML	V	TML.4V.39	TML.4
38	Nungkao	Tousem	93.33659	24.79109	666	TML	V	TML.2V.25	TML.2
39	Lubanglong	Nungba	93.56473	24.69691	665	TML	V	TML.4V.23	TML.4
40	Gallon	Nungba	93.23651	24.54069	595	TML	V	TML.4V.51	TML.4
41	Old mandu	Tousem	93.33913	25.06451	591	TML	V	TML.2V.07	TML.2
42	Kambiron	Nungba	93.38089	24.7359	589	TML	V	TML.4V.38	TML.4

43 Tamah	Tamei	93.6978	25.174	585 TML	V	TML.1V.12	TML.1
44 Thingra	Tamenglong	93.67481	25.00945	585 TML	V	TML.3V.34	TML.3
45 Joupi	Tamei	93.66334	25.25262	577 TML	V	TML.1V.10	TML.1
46 Kabui khullen	Tamenglong	93.65541	24.98138	567 TML	V	TML.3V.32	TML.3
47 Azuram	Tousem	93.42392	25.03639	559 TML	V	TML.2V.51	TML.2
48 Nungadangnaga	Nungba	93.58719	24.8643	555 TML	V	TML.4V.17	TML.4
49 Nagaching naga	Tamenglong	93.63061	24.93583	540 TML	V	TML.3V.30	TML.3
50 Keikao	Tamenglong	93.44076	24.84863	537 TML	V	TML.3V.16	TML.3
51 Bolongdai	Nungba	93.43752	24.75407	531 TML	V	TML.4V.35	TML.4
52 Saramba	Tousem	93.42018	25.01627	526 TML	V	TML.2V.50	TML.2
53 Taosang	Nungba	93.56718	24.73784	525 TML	V	TML.4V.26	TML.4
54 Khunphung	Tamei	93.64323	25.21095	521 TML	V	TML.1V.14	TML.1
55 Mongjarong	Nungba	93.5223	24.74418	521 TML	V	TML.4V.28	TML.4
56 Khongjaron khunkha	Tamenglong	93.4946	24.93479	520 TML	V	TML.3V.11	TML.3
57 Longpi	Nungba	93.34557	24.61962	515 TML	V	TML.4V.43	TML.4
58 Lukhambi	Tamenglong	93.55275	24.92367	498 TML	V	TML.3V.27	TML.3
59 Oktan	Tamenglong	93.70369	24.92464	491 TML	V	TML.3V.42	TML.3
60 Luwanglon khullen	Nungba	93.59465	24.66639	484 TML	V	TML.4V.13	TML.4
61 Khongsang	Nungba	93.45971	24.82897	484 TML	V	TML.4V.32	TML.4
62 Sibilong	Tousem	93.36407	24.79925	479 TML	V	TML.2V.38	TML.2
63 Sanglungpang	Tamenglong	93.44297	24.88631	478 TML	V	TML.3V.14	TML.3
64 Taningjam	Tousem	93.48603	25.15685	472 TML	V	TML.2V.55	TML.2
65 Longdi pabram	Tamenglong	93.50436	25.07342	464 TML	V	TML.3V.06	TML.3
66 Lamdangmei	Nungba	93.68879	24.72985	462 TML	V	TML.4V.05	TML.4
67 Bongaijang	Tamenglong	93.45033	24.8916	455 TML	V	TML.3V.13	TML.3
68 Aben	Tousem	93.28646	24.95166	445 TML	V	TML.2V.10	TML.2
69 Katang	Tousem	93.56743	25.18751	443 TML	V	TML.2V.59	TML.2
70 Joujangtek	Nungba	93.68318	24.65376	443 TML	V	TML.4V.09	TML.4
71 Nungtek	Tamenglong	93.67731	24.87371	442 TML	V	TML.3V.38	TML.3
72 Kaimai	Tousem	93.2672	24.71571	438 TML	V	TML.2V.27	TML.2
73 Longphailum	Nungba	93.27527	24.63592	436 TML	V	TML.4V.56	TML.4
74 Lamlaba	Tamei	93.62599	25.08578	430 TML	V	TML.1V.24	TML.1
75 Deigailong	Tamenglong	93.45188	24.96306	421 TML	V	TML.3V.09	TML.3
76 Atenba	Tousem	93.35369	24.92257	416 TML	V	TML.2V.41	TML.2
77 Namtiram	Tousem	93.4322	25.05803	415 TML	V	TML.2V.52	TML.2
78 Phoklong	Tousem	93.40568	25.16564	412 TML	V	TML.2V.05	TML.2
79 Dullen	Tamei	93.69189	25.22387	411 TML	V	TML.1V.11	TML.1
80 Impa	Tousem	93.56255	25.18389	408 TML	V	TML.2V.56	TML.2
81 Lasan	Tamei	93.78966	25.08721	389 TML	V	TML.1V.17	TML.1
82 Charoi Cha. PT2	Nungba	93.63365	24.7911	371 TML	V	TML.4V.02	TML.4
83 Buning	Tamei	93.58279	25.15359	347 TML	V	TML.1V.22	TML.1
84 Phelong	Tousem	93.45237	25.10286	345 TML	V	TML.2V.53	TML.2
85 Joute pabram	Tousem	93.37014	24.95045	341 TML	V	TML.2V.47	TML.2
86 Leisok	Nungba	93.57537	24.69548	337 TML	V	TML.4V.12	TML.4
87 Zampi	Tamei	93.62467	25.18425	326 TML	V	TML.1V.19.	TML.1
88 Pungmun	Tamenglong	93.69136	24.87898	324 TML	V	TML.3V.39	TML.3
89 Langpram	Tamei	93.52799	25.13431	320 TML	V	TML.1V.21	TML.1

90 Ponlen	Tamenglong	93.76118	24.94002	320 TML	V	TML.3V.43	TML.3
91 Inem	Tousem	93.48879	25.18542	316 TML	V	TML.2V.54	TML.2
92 Khudong Khunkhaiba	Tamei	93.73963	25.0266	315 TML	V	TML.1V.30	TML.1
93 Khongbung	Nungba	93.60387	24.62047	315 TML	V	TML.4V.10	TML.4
94 Khongjaron khunthak	Tamenglong	93.46858	24.94558	310 TML	V	TML.3V.10	TML.3
95 Leikot	Nungba	93.36782	24.67606	308 TML	V	TML.4V.48	TML.4
96 Kandihang	Tousem	93.31577	25.02975	307 TML	V	TML.2V.08	TML.2
97 Taobam	Tamenglong	93.47632	24.86663	306 TML	V	TML.3V.19	TML.3
98 Nungsai	Nungba	93.66845	24.65061	305 TML	V	TML.4V.11	TML.4
99 Bolkot	Tamei	93.68557	25.1676	304 TML	V	TML.1V.13	TML.1
100 Tingjang	Tamenglong	93.46838	24.85512	295 TML	V	TML.3V.18	TML.3
101 Atangkhullen	Tamei	93.70744	25.0677	294 TML	V	TML.1V.28	TML.1
102 Satu	Nungba	93.52273	24.68101	287 TML	V	TML.4V.16	TML.4
103 Taloulong	Tamei	93.64426	25.1136	286 TML	V	TML.1V.23	TML.1
104 Khebuching	Tamenglong	93.52297	24.91788	286 TML	V	TML.3V.21	TML.3
105 Okoklong	Nungba	93.40681	24.78486	265 TML	V	TML.4V.36	TML.4
106 Langkhong	Tamenglong	93.55085	24.84751	260 TML	V	TML.3V.24	TML.3
107 Changjal	Nungba	93.35073	24.70632	250 TML	V	TML.4V.50	TML.4

- Out of 109 villages with population more than 250, 2 villages (Ejeirong and Phaitol) are excluded as their coordinates in the data do not fall within this district boundary. Only 107 villages are shown in the GIS database.

Number villages taken up for cluster analysis = 107
Number of Block in the pilot district = 4

Sl. No.	x-ccord	y-coord	popltn	v_no	Bl-id
1	93.76296	25.32162	1444	1	1
2	93.67543	25.15260	1330	2	1
3	93.72780	25.34450	1134	3	1
4	93.81861	25.40336	1028	4	1
5	93.69038	25.31183	901	5	1
6	93.67611	25.27146	871	6	1
7	93.77299	25.35278	802	7	1
8	93.79714	25.41481	793	8	1
9	93.71959	25.24086	790	9	1
10	93.67073	25.13384	759	10	1
11	93.75766	25.39246	681	11	1
12	93.75362	25.15952	680	12	1
13	93.61609	25.04474	677	13	1
14	93.69780	25.17400	585	14	1
15	93.66334	25.25262	577	15	1
16	93.64323	25.21095	521	16	1
17	93.62599	25.08578	430	17	1
18	93.69189	25.22387	411	18	1
19	93.78966	25.08721	389	19	1
20	93.58279	25.15359	347	20	1
21	93.62467	25.18425	326	21	1
22	93.52799	25.13431	320	22	1
23	93.73963	25.02660	315	23	1
24	93.68557	25.16760	304	24	1
25	93.70744	25.06770	294	25	1
26	93.64426	25.11360	286	26	1
1	93.37842	25.11623	1181	27	2
2	93.29117	24.75432	958	28	2
3	93.40430	24.99306	732	29	2
4	93.54664	25.22371	676	30	2
5	93.33659	24.79109	666	31	2
6	93.33913	25.06451	591	32	2
7	93.42392	25.03639	559	33	2
8	93.42018	25.01627	526	34	2
9	93.36407	24.79925	479	35	2
10	93.48603	25.15685	472	36	2
11	93.28646	24.95166	445	37	2
12	93.56743	25.18751	443	38	2
13	93.26720	24.71571	438	39	2
14	93.35369	24.92257	416	40	2
15	93.43220	25.05803	415	41	2
16	93.40568	25.16564	412	42	2
17	93.56255	25.18389	408	43	2
18	93.45237	25.10286	345	44	2
19	93.37014	24.95045	341	45	2
20	93.48879	25.18542	316	46	2
21	93.31577	25.02975	307	47	2

1	93.50797	25.00810	7733	48	3
2	93.67905	24.81927	1268	49	3
3	93.54878	24.85412	1147	50	3
4	93.49229	24.91279	1002	51	3
5	93.57031	24.97195	996	52	3
6	93.54096	25.05449	864	53	3
7	93.52326	25.02928	838	54	3
8	93.67322	24.88577	828	55	3
9	93.55735	24.88122	793	56	3
10	93.57389	24.93180	781	57	3
11	93.63182	25.05285	713	58	3
12	93.67481	25.00945	585	59	3
13	93.65541	24.98138	567	60	3
14	93.63061	24.93583	540	61	3
15	93.44076	24.84863	537	62	3
16	93.49460	24.93479	520	63	3
17	93.55275	24.92367	498	64	3
18	93.70369	24.92464	491	65	3
19	93.44297	24.88631	478	66	3
20	93.50436	25.07342	464	67	3
21	93.45033	24.89160	455	68	3
22	93.67731	24.87371	442	69	3
23	93.45188	24.96306	421	70	3
24	93.69136	24.87898	324	71	3
25	93.76118	24.94002	320	72	3
26	93.46858	24.94558	310	73	3
27	93.47632	24.86663	306	74	3
28	93.46838	24.85512	295	75	3
29	93.52297	24.91788	286	76	3
30	93.55085	24.84751	260	77	3
1	93.52241	24.71481	2996	78	4
2	93.63022	24.84076	2230	79	4
3	93.53488	24.76783	1315	80	4
4	93.42619	24.74321	1245	81	4
5	93.63603	24.71885	947	82	4
6	93.66937	24.66021	896	83	4
7	93.51010	24.78334	866	84	4
8	93.55642	24.63047	853	85	4
9	93.41309	24.65001	671	86	4
10	93.56473	24.69691	665	87	4
11	93.23651	24.54069	595	88	4
12	93.38089	24.73590	589	89	4
13	93.58719	24.86430	555	90	4
14	93.43752	24.75407	531	91	4
15	93.56718	24.73784	525	92	4
16	93.52230	24.74418	521	93	4
17	93.34557	24.61962	515	94	4
18	93.59465	24.66639	484	95	4
19	93.45971	24.82897	484	96	4
20	93.68879	24.72985	462	97	4
21	93.68318	24.65376	443	98	4
22	93.27527	24.63592	436	99	4
23	93.63365	24.79110	371	100	4
24	93.57537	24.69548	337	101	4
25	93.60387	24.62047	315	102	4
26	93.36782	24.67606	308	103	4

27	93.66845	24.65061	305	104	4
28	93.52273	24.68101	287	105	4
29	93.40681	24.78486	265	106	4
30	93.35073	24.70632	250	107	4
1	93.67543	25.15260	1330	2	1
2	93.37842	25.11623	1181	27	2
3	93.50797	25.00810	7733	48	3
4	93.42619	24.74321	1245	81	4

Table-C1

Model-1 output: Tamenglong district, Cluster data

Block-1:Tamei
Total road length (in m) for this block = 290193

Total population served in this block = 19143

Population served per km length of road = 65

Block-2:Tousem
Total road length (in m) for this block = 39023.5

Total population served in this block = 4484

Population served per km length of road = 114

Block-3:Tamenglong
Total road length (in m) for this block = 153711

Total population served in this block = 28402

Population served per km length of road = 184

Block-4:Nungba
Total road length (in m) for this block = 221479

Total population served in this block = 22416

Population served per km length of road = 101

Table-C2

Model-1 output: Tamenglong district, Administrative data

Block-1:Tamei
Total road length (in m) for this block = 149417

Total population served in this block = 16995

Population served per km length of road = 113

Block-2:Tousem

Total road length (in m) for this block = 125760

Total population served in this block = 11126

Population served per km length of road = 88

Block-3:Tamenglong
Total road length (in m) for this block = 133262

Total population served in this block = 25062

Population served per km length of road = 188

Block-4:Nungba
Total road length (in m) for this block = 130578

Total population served in this block = 21262

Population served per km length of road = 162

Table-C3

Model-2 output: Tamenglong district, Cluster data

Block-1:Tamei

****

Cycle [1] Population = 19143 Distance (in mtr) = 49854.5
Threshold assumed (in mtr) = 18505.7
Population served per km = 383.977

Cycle [2] Population = 19143 Distance (in mtr) = 50090.6
Threshold assumed (in mtr) = 22206.8
Population served per km = 382.168

Cycle [3] Population = 19143 Distance (in mtr) = 49092.8
Threshold assumed (in mtr) = 25907.9
Population served per km = 389.935

Cycle [4] Population = 19143 Distance (in mtr) = 49092.8
Threshold assumed (in mtr) = 29609
Population served per km = 389.935

++++++++*************************************++++++++

Proposed threshold (in mtr) = 25907.9
Expected population to be served = 19143
Proposed length of road network (in mtr) = 49092.8

++++++++*************************************++++++++

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
1	18505.7	49854.5	19143	383.977	0

1 22 13 10 24 16 28 30 8451.6
1 20 15 14 6 5 3 2 7 11 8 4 15427.2
1 17 9 12 6783.5
1 23 21 18 29 13000.7
1 19 27 26 25 6191.53

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
2	22206.8	50090.6	19143	382.168	0

1 22 13 10 24 16 28 30 23 10788.4
1 20 15 14 6 5 3 2 7 11 8 4 15427.2
1 17 9 12 18 9611.28
1 19 27 26 25 6191.53
1 21 29 8072.19

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
3	25907.9	49092.8	19143	389.935	1

1 22 13 10 24 16 28 30 23 21 12615.5
1 20 15 14 6 5 3 2 7 11 8 4 15427.2
1 17 9 12 18 29 14858.5
1 19 27 26 25 6191.53

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
4	29609	49092.8	19143	389.935	0

1 22 13 10 24 16 28 30 23 21 12615.5
1 20 15 14 6 5 3 2 7 11 8 4 15427.2
1 17 9 12 18 29 14858.5
1 19 27 26 25 6191.53

Block-2:Tousem C3-cd/M2

****

Cycle [1] Population = 4484 Distance (in mtr) = 19088.6
Threshold assumed (in mtr) = 8322.94
Population served per km = 234.905

Cycle [2] Population = 4484 Distance (in mtr) = 19088.6
Threshold assumed (in mtr) = 9987.53
Population served per km = 234.905

Cycle [3] Population = 4484 Distance (in mtr) = 19088.6
Threshold assumed (in mtr) = 11652.1
Population served per km = 234.905

Cycle [4] Population = 4484 Distance (in mtr) = 18122.8
Threshold assumed (in mtr) = 13316.7
Population served per km = 247.423

++++++++************************************++++++++

Proposed threshold (in mtr) = 13316.7
Expected population to be served = 4484
Proposed length of road network (in mtr) = 18122.8

++++++++************************************++++++++

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
1	8322.94	19088.6	4484	234.905	0
1 6 7	4713.48				
1 2 9 4	6658.36				
1 5 3 8	7716.75				
2	9987.53	19088.6	4484	234.905	0
1 6 7	4713.48				
1 2 9 4	6658.36				
1 5 3 8	7716.75				
3	11652.1	19088.6	4484	234.905	0
1 6 7	4713.48				
1 2 9 4	6658.36				
1 5 3 8	7716.75				
4	13316.7	18122.8	4484	247.423	1
1 6 7 5	6434.07				
1 2 9 4	6658.36				
1 3 8	5030.39				

Block-3:Tamenglong C3-cd/M2

****

Cycle [1]   Population = 28402   Distance (in mtr) = 52176.6
Threshold assumed (in mtr) = 16058
Population served per km = 544.344

Cycle [2]   Population = 28402   Distance (in mtr) = 57265.7
Threshold assumed (in mtr) = 19269.6
Population served per km = 495.969

Cycle [3]   Population = 28402   Distance (in mtr) = 54655.4
Threshold assumed (in mtr) = 22481.2
Population served per km = 519.656

Cycle [4]   Population = 28402   Distance (in mtr) = 54661.1
Threshold assumed (in mtr) = 25692.8
Population served per km = 519.601

++++++++*************************************++++++++

Proposed threshold (in mtr) = 16058
Expected population to be served = 28402
Proposed length of road network (in mtr) = 52176.6

++++++++*************************************++++++++

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
1	16058	52176.6	28402	544.344	1

1 14 13 24 2 5720.81
1 27 29 20 11 30 21 7274.33
1 12 17 16 10 32 31 9 26 15 28 14795
1 5 4 3 7 6 8511.44
1 8 18 19 22 11008.4
1 25 23 4866.59

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
2	19269.6	57265.7	28402	495.969	0

1 14 13 24 2 5720.81
1 27 29 20 11 30 21 17 12 9477.92
1 5 4 3 7 6 8511.44
1 8 18 19 15 26 28 22 9 17135.4
1 25 23 10 8737.6
1 16 32 31 7682.51

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
3	22481.2	54655.4	28402	519.656	0

1 14 13 24 2 8 10118
1 27 29 20 11 30 21 17 12 9477.92
1 5 4 3 7 6 8511.44
1 25 23 10 16 32 31 9 14516.8
1 19 18 22 28 26 15 12031.3

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
4	25692.8	54661.1	28402	519.601	0

1 14 13 24 2 8 18 12727.9
1 27 29 20 11 30 21 17 12 19 15 26 28 15209.8
1 5 4 3 7 6 23 25 12201.4
1 16 10 32 31 9 22 14522

Block-4: Nungba C3-cd/M2

****

Cycle [1] Population = 22416 Distance (in mtr) = 70104.5
Threshold assumed (in mtr) = 15686
Population served per km = 319.751
Cycle [2] Population = 22416 Distance (in mtr) = 70104.5
Threshold assumed (in mtr) = 18823.2
Population served per km = 319.751
Cycle [3] Population = 22416 Distance (in mtr) = 70104.5
Threshold assumed (in mtr) = 21960.4
Population served per km = 319.751
Cycle [4] Population = 22416 Distance (in mtr) = 66476.2
Threshold assumed (in mtr) = 25097.6
Population served per km = 337.203

+++++++**********************************+++++++

Proposed threshold (in mtr) = 25097.6
Expected population to be served = 22416
Proposed length of road network (in mtr) = 66476.2

+++++++**********************************+++++++

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
1	15686	70104.5	22416	319.751	0

1 20 35 3 2 11 4 28 11096
1 19 36 32 16 23 18 13432.7
1 25 5 7 6 8 8354.08
1 14 10 22 9 34 17 30 24 31 12235.6
1 21 12 26 13 33 27 12719.4
1 15 29 12266.8

2	18823.2	70104.5	22416	319.751	0

1 20 35 3 2 11 4 28 11096
1 19 36 32 16 23 18 13432.7
1 25 5 7 6 8 8354.08
1 14 10 22 9 34 17 30 24 31 12235.6
1 21 12 26 13 33 27 12719.4
1 15 29 12266.8

3	21960.4	70104.5	22416	319.751	0

1 20 35 3 2 11 4 28 11096
1 19 36 32 16 23 18 13432.7
1 25 5 7 6 8 8354.08
1 14 10 22 9 34 17 30 24 31 12235.6
1 21 12 26 13 33 27 12719.4
1 15 29 12266.8

4	25097.6	66476.2	22416	337.203	1

1 20 35 3 2 11 4 28 11096
1 19 36 32 16 23 18 13432.7
1 25 5 7 6 8 14 10 12037.8
1 22 9 34 17 30 24 31 15 12080.5
1 21 12 26 13 33 27 29 17829.3

Table-C4
Model-2 output: Tamenglong district, Administrative data
Block-1:Tamei
****

Cycle [1]　Population = 16995　Distance (in mtr) = 41860.6
Threshold assumed (in mtr) = 18505.7
Population served per km = 405.991

Cycle [2]　Population = 16995　Distance (in mtr) = 48543.2
Threshold assumed (in mtr) = 22206.8
Population served per km = 350.1

Cycle [3]　Population = 16995　Distance (in mtr) = 42058.9
Threshold assumed (in mtr) = 25907.9
Population served per km = 404.076

Cycle [4]　Population = 16995　Distance (in mtr) = 44721.6
Threshold assumed (in mtr) = 29609
Population served per km = 380.018
++++++++**********************************++++++++
Proposed threshold (in mtr) = 18505.7
Expected population to be served = 16995
Proposed length of road network (in mtr) = 41860.6
++++++++**********************************++++++++

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
1	18505.7	41860.6	16995	405.991	1

1 24 14 10 2 17 13 6620.66
1 21 16 15 6 5 3 26 7 11 8 4 15427.2
1 18 9 12 6783.5
1 25 23 19 7753.46
1 20 22 5275.77

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
2	22206.8	48543.2	16995	350.1	0

1 24 14 10 2 17 13 25 9917.49
1 21 16 15 6 5 3 26 7 11 8 4 15427.2
1 18 9 12 19 9611.28
1 20 22 23 13587.3

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
3	25907.9	42058.9	16995	404.076	0

1 24 14 10 2 17 13 25 23 11744.6
1 21 16 15 6 5 3 26 7 11 8 4 15427.2
1 18 9 12 19 9611.28
1 20 22 5275.77

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
4	29609	44721.6	16995	380.018	0

1 24 14 10 2 17 13 25 23 19 14495.2
1 21 16 15 6 5 3 26 7 11 8 4 15427.2
1 18 9 12 20 22 14799.2

Block-2:Tousem C4-ad/M2

****

Cycle [1] Population = 11126 Distance (in mtr) = 39258.6
Threshold assumed (in mtr) = 23596.7
Population served per km = 283.403

Cycle [2] Population = 11126 Distance (in mtr) = 39258.6
Threshold assumed (in mtr) = 28316.1
Population served per km = 283.403

Cycle [3] Population = 11126 Distance (in mtr) = 46580.2
Threshold assumed (in mtr) = 33035.4
Population served per km = 238.857

Cycle [4] Population = 11126 Distance (in mtr) = 46670.6
Threshold assumed (in mtr) = 37754.8
Population served per km = 238.394

++++++++************************************++++++++
Proposed threshold (in mtr) = 23596.7
Expected population to be served = 11126
Proposed length of road network (in mtr) = 39258.6
++++++++************************************++++++++

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
1	23596.7	39258.6	11126	283.403	1

1 16 18 15 7 8 3 19 14 11990
1 6 21 11 5 9 2 13 18136.7
1 10 20 4 12 17 9131.97

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
2	28316.1	39258.6	11126	283.403	0

1 16 18 15 7 8 3 19 14 11990
1 6 21 11 5 9 2 13 18136.7
1 10 20 4 12 17 9131.97

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
3	33035.4	46580.2	11126	238.857	0

1 16 18 15 7 8 3 19 14 11 14553.9
1 6 21 10 20 4 12 17 16281.4
1 9 5 2 13 15744.9

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
4	37754.8	46670.6	11126	238.394	0

1 16 18 15 7 8 3 19 14 11 21 17473.2
1 6 10 20 4 12 17 13452.5
1 9 5 2 13 15744.9

Block-3:Tamenglong C4-ad/M2
****

Cycle [1]   Population = 25062   Distance (in mtr) = 48635.4
Threshold assumed (in mtr) = 19328.4
Population served per km = 515.304

Cycle [2]   Population = 25062   Distance (in mtr) = 48189.3
Threshold assumed (in mtr) = 23194.1
Population served per km = 520.074

Cycle [3]   Population = 25062   Distance (in mtr) = 47173.6
Threshold assumed (in mtr) = 27059.7
Population served per km = 531.272

Cycle [4]   Population = 25062   Distance (in mtr) = 50139.5
Threshold assumed (in mtr) = 30925.4
Population served per km = 499.845

++++++++***********************************++++++++
Proposed threshold (in mtr) = 27059.7
Expected population to be served = 25062
Proposed length of road network (in mtr) = 47173.6
++++++++***********************************++++++++

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
1	19328.4	48635.4	25062	515.304	0

1 7 6 20 5 10 9081.29
1 23 26 16 4 29 17 9 3 30 10006
1 21 19 15 28 27 7670.19
1 11 12 13 14 8 22 24 18 25 2 21877.9

2	23194.1	48189.3	25062	520.074	0

1 7 6 20 5 10 17 29 10935.8
1 23 26 16 4 21 19 15 28 27 9889.9
1 11 12 13 14 8 22 24 18 25 16766.7
1 9 3 30 2 10596.9

3	27059.7	47173.6	25062	531.272	1

1 7 6 20 5 10 17 29 4 16 12798.7
1 23 26 21 19 15 28 27 3 30 9 12497
1 11 12 13 14 8 22 24 18 25 2 21877.9

4	30925.4	50139.5	25062	499.845	0

1 7 6 20 5 10 17 29 4 16 26 23 14630.6
1 21 19 15 28 27 3 30 9 14 14886
1 11 12 13 18 24 22 8 2 25 20622.9

Block-4:Nungba C4-ad/M2

****

Cycle [1] Population = 21262 Distance (in mtr) = 60706.9
Threshold assumed (in mtr) = 15686
Population served per km = 350.24

Cycle [2] Population = 21262 Distance (in mtr) = 62167.2
Threshold assumed (in mtr) = 18823.2
Population served per km = 342.013

Cycle [3] Population = 21262 Distance (in mtr) = 60684.1
Threshold assumed (in mtr) = 21960.4
Population served per km = 350.372

Cycle [4] Population = 21262 Distance (in mtr) = 79216.4
Threshold assumed (in mtr) = 25097.6
Population served per km = 268.404

++++++++************************************++++++++

Proposed threshold (in mtr) = 21960.4
Expected population to be served = 21262
Proposed length of road network (in mtr) = 60684.1

++++++++************************************++++++++

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
1	15686	60706.9	21262	350.24	0

1 14 29 12 4 26 6705.27
1 19 7 3 16 7562.78
1 9 17 22 11 12010.1
1 30 28 10 24 18 25 8 11199.7
1 15 5 20 6 27 21 12719.4
1 13 2 23 10509.7

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
2	18823.2	62167.2	21262	342.013	0

1 14 29 12 4 26 9 8533.42
1 19 7 3 16 30 8590.78
1 28 10 24 18 25 8 10524.9
1 15 5 20 6 27 21 12719.4
1 17 22 11 11289.1
1 13 2 23 10509.7

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
3	21960.4	60684.1	21262	350.372	1

1 14 29 12 4 26 9 8533.42
1 19 7 3 16 30 28 9773.83
1 15 10 24 18 25 8 27 6 21 16161.7
1 17 22 11 11289.1
1 13 2 23 5 20 14926.1

Sl No.	Thresh dis (in mtr)	Road length (in mtr)	Popultn served	Popultn srvd/km	Remark
4	25097.6	79216.4	21262	268.404	0

1 14 29 12 4 26 9 17 11125
1 19 7 3 16 30 28 10 24 18 25 14582.2
1 15 5 20 6 27 21 12719.4
1 8 23 2 14009
1 22 11 13 26780.8

Table-C5
Model-3 output: Tamenglong district, Cluster data

Block-1:Tamei

---

mf=1.25*

Total length of the whole road network (mtrs) = 65795

Population served = 19143

Population served per km length of road network = 290

---

mf=1.50

Total length of the whole road network (mtrs) = 70577

Population served = 19143

Population served per km length of road network = 271

---

mf=1.75

Total length of the whole road network (mtrs) = 66804

Population served = 19143

Population served per km length of road network = 286

---

mf=2.00

Total length of the whole road network (mtrs) = 66804

Population served = 19143

Population served per km length of road network = 286

Block-2:Tousem C5-cd/M3

---

mf=1.25

Total length of the whole road network (mtrs) = 22778

Population served = 4484

Population served per km length of road network = 196

---

mf=1.50

Total length of the whole road network (mtrs) = 22778

Population served = 4484

Population served per km length of road network = 196

---

mf=1.75*

Total length of the whole road network (mtrs) = 21725

Population served = 4484

Population served per km length of road network = 206

---

mf=2.00

Total length of the whole road network (mtrs) = 21725

Population served = 4484

Population served per km length of road network = 206

Block-3:Tamenglong C5-cd/M3

---

mf =1.25*

Total length of the whole road network (mtrs) = 66835

Population served = 28402

Population served per km length of road network = 424

---

mf=1.50

Total length of the whole road network (mtrs) = 69963

Population served = 28402

Population served per km length of road network = 405

---

mf=1.75

Total length of the whole road network (mtrs) = 68662

Population served = 28402

Population served per km length of road network = 413

---

mf=2.00

Total length of the whole road network (mtrs) = 68312

Population served = 28402

Population served per km length of road network = 415

Block-4:Nungba C5-cd/M3

---

mf=1.25*

Total length of the whole road network (mtrs) = 81061

Population served = 22416

Population served per km length of road network = 276

---

mf=1.50

Total length of the whole road network (mtrs) = 90508

Population served = 22416

Population served per km length of road network = 247

---

mf=1.75

Total length of the whole road network (mtrs) = 89988

Population served = 22416

Population served per km length of road network = 249

---

mf=2.00

Total length of the whole road network (mtrs) = 90568

Population served = 22416

Population served per km length of road network = 247

Table-C6
Model-3 output: Tamenglong district, Administrative data

Block-1:Tamei

---

mf=1.25*

Total length of the whole road network (mtrs) = 55587

Population served = 16995

Population served per km length of road network = 305

---

mf=1.50

Total length of the whole road network (mtrs) = 55587

Population served = 16995

Population served per km length of road network = 305

---

mf=1.75

Total length of the whole road network (mtrs) = 59270

Population served = 16995

Population served per km length of road network = 286

---

mf=2.00

Total length of the whole road network (mtrs) = 59270

Population served = 16995

Population served per km length of road network = 286

Block-2:Tousem C6-ad/M3

---

mf=1.25

Total length of the whole road network (mtrs) = 66200

Population served = 11126

Population served per km length of road network = 168

---

mf=1.50

Total length of the whole road network (mtrs) = 66200

Population served = 11126

Population served per km length of road network = 168

---

mf=1.75

Total length of the whole road network (mtrs) = 62462

Population served = 11126

Population served per km length of road network = 178

---

mf=2.00*

Total length of the whole road network (mtrs) = 59141

Population served = 11126

Population served per km length of road network = 188

Block-3:Tamenglong C6-ad/M3

---

mf=1.25

Total length of the whole road network (mtrs) = 73142

Population served = 25062

Population served per km length of road network = 342

---

mf=1.50*

Total length of the whole road network (mtrs) = 72605

Population served = 25062

Population served per km length of road network = 345

---

mf=1.75

Total length of the whole road network (mtrs) = 80756

Population served = 25062

Population served per km length of road network = 310

---

mf=2.00

Total length of the whole road network (mtrs) = 81603

Population served = 25062

Population served per km length of road network = 307

Block-4:Nungba C6-ad/M3

---

mf=1.25*

Total length of the whole road network (mtrs) = 87885

Population served = 21262

Population served per km length of road network = 241

---

mf=1.50

Total length of the whole road network (mtrs) = 92839

Population served = 21262

Population served per km length of road network = 229

---

mf=1.75

Total length of the whole road network (mtrs) = 102527

Population served = 21262

Population served per km length of road network = 207

---

mf=2.00

Total length of the whole road network (mtrs) = 101708

Population served = 21262

Population served per km length of road network = 209
